Rec'd PCT/PTO 11 MAR 2005

PCT/A 03/01211

10/527608

REC'D 30 SEP 2003

WIPO PCT

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PROVISIONAL SPECIFICATION

for the invention entitled:

"GAS APPLIANCES"

The invention is described in the following statement:

GAS APPLIANCES

This invention relates to gas appliances.

More particularly, the invention relates to gas appliances which can be used for heating water such as for instance for use in domestic hot water supplies or for use in hydronic heating systems.

The general objective of the invention is to improve the efficiency of gas appliances.

According to the present invention there is provided gas water heating apparatus including:

a storage tank for storing heated water;

a gas burner for heating water stored in the storage tank;

air supply means for supplying air to the burner;

gas supply means for adding gas to the air which is supplied to the burner; and

control means for controlling the amount of gas supplied to the burner by controlling the flow of air to the burner.

Preferably the air supply means includes first and second fans and the control means is operable to independently control the fans.

Preferably further, the control means includes first and second temperature sensors for sensing the temperature of water in the storage tank, the sensors being coupled to control the first and second fans respectively.

In one embodiment the fans are of the same capacity but the first fan has flow restricting means associated therewith to restrict airflow therethrough.

In another embodiment, the first fan has a relatively low airflow rate and the second fan has a relatively high airflow rate.

In a further embodiment, a single fan is used which has dual speeds for supplying air at high and low rates.

In accordance with a further aspect of the invention there is provided, combustion apparatus including:

a heat exchanger;

a gas burner;

fuel supply means for supplying a gas air mixture to the gas burner;

a flue for removal of combustion products from the gas burner; and

control means for controlling the rate of supply of gas air mixture to the burner by controlling the rate of flow of combustion products in the flue.

Preferably, the flue includes valve means.

The invention also provides a method of controlling a gas burner including the steps of:

providing a supply of air to the burner;

introducing gas into the supply of air at a rate which is proportional to the rate of flow of air in said supply to form a gas-air mixture;

igniting the gas in the burner to produce flue gases;

directing the flue gases into a flue; and

controlling the rate of flow of flue gases in the flue to thereby effectively control the rate of supply of gas-air mixture to the burner.

In accordance with a further aspect of the invention, there is provided combustion apparatus including:

a heat exchanger;

a gas burner;

gas supply means for supplying a gas air mixture to the burner;

a flue for removal of combustion products from the gas burner; and

valve means in said flue, said valve means being operable to close said flue when the pressure of combustion products is below a predetermined value.

The arrangement defined above has improved efficiency because it avoids standby losses arising from convection currents which normally would flow through the flue when the gas burner is not operating. This is because the flue is blocked when the gas burner is not operating.

Preferably the apparatus includes control means which is arranged to control the apparatus in multiple modes of operation including:

a first standby mode;

a low heating mode; and

a high heating mode

the control means being operable to control the gas supply means such that:

(i) in said standby mode, there is zero or substantially zero gas air mixture supplied to the burner;

(ii) in said low heating mode, there is a relatively low rate of gas air mixture supplied to the burner whereby the pressure of combustion products causes the flue valve means to open by a relatively low amount; and

(iii) in said high heating mode, there is a relatively high rate of air gas mixture supplied to the burner thereby causing the pressure of combustion products to open the valve means by a relatively high amount.

Preferably further, the gas burner is arranged to heat water in a storage tank and wherein an electric element is provided for heating the water in the storage tank and wherein the control means is operable to control the apparatus in a fourth mode of operation, being an emergency mode in which the electric element can be used for heating the water in the tank if the gas supply is lost.

According to a further aspect of the invention there is provided combustion apparatus including:

a heat exchanger;

a gas burner;

gas supply means for supplying a gas mixture to the burner;

a flue for removal of combustion products from the gas burner;

valve means in said flue, said valve means being operable to close said flue when the predetermined pressure of combustion products is below a predetermined value;

control means which is arranged to control the apparatus in three modes of operation:

a first standby mode;

a low heating mode; and

a high heating mode

the control means being operable to control the gas supply means such that:

(i) in said standby mode, there is zero or substantially zero gas air mixture supplied to the burner;

(ii) in said low heating mode, there is a relatively low rate of gas air mixture supplied to the burner whereby the pressure of combustion products causes the flue valve means to open by a relatively low amount; and

(iii) in said high heating mode, the control means is operable to activate valve means and cause it to move to a fully open position.

In this arrangement, in the low heating mode, the valve means in the flue normally is only partly opened by the relatively low volume of combustion products flowing therethrough. When, however, a higher heating rate is required, additional gas air mixture is supplied to the burner and simultaneously the control means opens the valve means in the flue to permit substantially higher flows of flue gas therethrough.

Again, this arrangement is efficient because it avoids standby losses caused by convection currents which would normally flow through the flue when the burner is not operating.

According to a further aspect of the invention there is provided water heating apparatus including:

a storage tank for storing heated water;

a gas burner for heating water stored in the storage tank;

air supply means for supplying air to the burner;

gas supply means for adding gas to the air which is supplied to the burner; and

a heat exchange coil located in the tank characterised in that the coil is of generally frustoconical shape.

In this arrangement, when the gas burner is operated there will be relatively cold water flowing to the coil relative to the heated water in the storage tank and cold convection currents will be generated adjacent to the coil. Because of the orientation of the coil, that is to say with the wider end at the bottom of the tank, the cold convection currents in the storage tank will tend not to be directed towards lower convolutions in the coil. This enhances heat transfer because relatively hotter water is adjacent to the heat transfer coil.

According to a further aspect of the invention there is provided water heating apparatus including:

a storage tank for storing heated water;

a gas burner for heating water stored in the storage tank;

air supply means for supplying air to the burner;

a gas supply means for adding gas to the air which is supplied to the burner, characterised in that the burner is, in use, immersed in water in the storage tank.

In this arrangement, because the burner is immersed in the water there is increased heat transfer to the water. Normally, the lower part of the burner is exposed to air and so radiation and/or conduction losses can occur.

Preferably, a flue is connected to the burner for removal of combustion products therefrom. Preferably further, the flue extends vertically through the tank and further heat

transfer can occur from the surface of the flue.

According to a further aspect of the invention there is provided water heating apparatus including:

a storage tank for storing heated water;

a gas burner for heating water stored in the storage tank;

air supply means for supplying air to the burner;

gas supply means for adding water to the air which is supplied to the burner;

an electric heating element for heating the water stored in the storage tank; and

control means for controlling operation of the gas burner and the electric heating element in different modes.

In a normal mode, the control means is operable to operate solely the gas burner.

In a high demand mode, the gas burner and electric heating element are operated simultaneously.

In an emergency supply mode, the gas burner can still be operated in conditions where electric power is restricted. Where power restrictions apply, they normally only apply to appliances which draw high currents. In the water heater of the invention, the fan required for operating the gas burner would be of relatively low capacity, say of the order of 100 to 150 watts and therefore its use would be permissible in times of electric power restrictions. In the event that the gas supply fails, the electric heating element alone can be used to supply some hot water to the consumer, even though the rate of replenishment of hot water would be relatively low. This, nevertheless, would be preferable to not having any hot water at all.

According to a further aspect of the invention there is provided an immersible gas burner assembly, the burner assembly including:

a waterproof housing;

a gas burner located within the housing;

an inlet for admission of gas air mixture to the burner; and

a flue outlet for escape of combustion products from the housing.

Preferably, the housing includes passages therethrough for permitting water convection currents to flow therethrough when the housing is immersed in water.

Preferably further, there is a plurality of said passages which are disposed between the burner and the flue outlet and which are arranged to cause the combustion products to flow from the burner towards the flue outlet adjacent to the inside surfaces of said housing. This enhances heat transfer to the water in which the housing is immersed.

According to a further aspect of the invention there is provided a water heating system including:

a water storage tank;

a gas burner for heating water in the storage tank;

a first heat exchange coil in the tank;

a solar absorbent panel;

a solar heating storage tank;

circulating means for circulating water from the solar heater storage tank to the absorbent panel so that, in use, solar energy heats the water from the solar heater storage tank; and

a second heat exchange coil located in the solar heater storage tank, characterised in that the first and second heat exchange coils are connected in series whereby, in use, cold water is supplied to the second coil so that the solar heater storage tank serves as a pre-heater for water passing to the first heat exchange coil in the hot water storage tank.

Preferably, the solar absorbent panel includes a flue gas inlet and a flue gas outlet whereby flue gases from the gas burner can be coupled thereto so that, in use, heat from the flue gases can be transferred to water circulating through the solar absorbent panel.

This arrangement has the advantage that heat in the flue gases is not lost but instead can be used to preheat water which is passed to the hot water storage tank in addition to heating attributable to solar energy absorbed by the panel.

According to a further aspect of the invention there is provided a water heating system including:

a first water storage tank;

a gas burner for heating water in the storage tank;

a solar absorbent panel;

a second water storage tank;

circulating means for circulating water from the second water storage tank to the absorbent panel so that in use solar energy heats water from the second water storage tank and a heat exchange coil located in the second water storage tank characterised in that cold water is supplied to the heat exchange coil and then to an inlet to said first water storage tank so that the second water storage tank serves as a pre-heater for water passing to the first water storage tank. In this system the first water storage tank could be a substantially conventional mains pressure hot water system and, generally speaking, the solar absorbent panel and second water storage tank are used as a pre-heater for the mains pressure system whereby increased efficiency is obtained.

In a modification of the arrangements defined above, the heated water in the second water storage tank could be used as the medium for an hydronic heating system.

In one arrangement, the panel includes ducts for the flue gas, the ducts being in heat transfer contact with the water circulating through the panel.

In an alternative arrangement, the panel is arranged such that the flue gas bubbles through the water circulating through the panel.

According to a further aspect of the invention there is provided a water heating system including:

a water storage tank;

a gas burner for heating water in the storage tank;

a first heat exchange coil in the tank;

a solar absorbent panel;

a solar heating storage tank;

circulating means for circulating water from the solar heater storage tank to the absorbent panel so that, in use, solar energy heats the water from the solar heater storage tank;

a second heat exchange coil located in the solar heater storage tank, characterised in that the first and second heat exchange coils are connected in series whereby, in use, cold water is supplied to the second coil so that the solar heater storage tank serves as a pre-heater for water passing to the first heat exchange coil in the hot water storage tank;

an internal combustion engine;

an electric generator coupled to the engine;

a storage battery which is charged by said generator;

characterised in that exhaust gases from the internal combustion engine are passed through said panel so that water circulating therethrough extracts heat energy from said exhaust gases.

Various embodiments of the water heaters disclosed herein incorporate novel features which enhance the overall efficiency. These features include a novel pre-heater tank which is preferably of the same general construction as the storage tank. This leads to efficiencies in manufacturing and inventory.

The invention also provides a combined water heater and pre-heater tank constructed as a single unit. This leads to manufacturing and thermal efficiencies. Preferably, the water heater tank is located directly above the pre-heater tank and located within the same housing. The storage tank and pre-heater tanks may include reinforcing rods to reinforce the ends thereof to prevent buckling when the pressure therein is above atmospheric.

The invention also provides a novel solar panel which has an additional chamber therein for circulation of flue and/or exhaust gases therein for transfer of heat therefrom to the water flowing through a solar collector panel.

The invention also provides a combined hot water and pre-heater unit in which the pre-heater unit is provided with a heat exchanger for extraction of heat from flue gases from a burner assembly within the water storage tank.

The combined unit may also include a further heat exchanger which extracts any residual heat from the heat exchanger within the pre-heater tank to pass it to cold water being admitted to the pre-heater tank.

The invention will now be further described with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a hot water heater constructed in accordance with the invention;

Figure 2A is a schematic view of the heater showing typical plumbing connections thereto;

Figure 2B is a schematic view of a modified heater;

Figure 3 is a similar view to Figure 2 but showing the heater incorporating a remote header tank;

Figures 4A, 4B and 4C are schematic views of the water heater showing the gas burner and heat transfer coil in different operating conditions;

Figure 5 is a diagrammatic cross-sectional view through the burner assembly along the line 5-5;

Figure 6 is a schematic view of a modified water heater;

Figures 7A and 7B are schematic views of other modified water heaters;

Figure 8 is a schematic view of another modified water heater;

Figure 9A is a schematic view of a gas-solar water heating system;

Figure 9B is a typical control circuit for the system of Figure 9A;

Figure 10 is a schematic view of a solar storage tank;

Figure 11A is a schematic plan view of a solar collector panel;

Figure 11B is a schematic cross-sectional view along the line 11B-11B;

Figure 12A is a schematic cross-sectional view along the line 12A-12A;

Figure 12B is a schematic plan view of another solar collector panel;

Figure 13 is a schematic view through a modified gas-solar water heating system;

Figure 14 diagrammatically shows the system of Figure 13 in a different state of operation;

Figure 15A is a schematic view of another modified gas-solar water heating system;

Figure 15B schematically shows the system of Figure 15A in a different state of operation;

Figure 16A is a fragmentary view of part of a modified gas-solar water heating system;

Figure 16B is a fragmentary view of part of another modified gas-solar water heating system;

Figure 17 schematically shows another gas-solar water heating system which includes a motor generator set;

Figures 18A and 18B show another modified gas-solar water heating system under different operating conditions;

Figure 19 is another modified gas-solar water heating system;

Figure 20 is another modified gas-solar water heating system;

Figure 21 is another modified gas-solar water heating system;

Figures 22 and 23 illustrate a further modified hot water heater constructed in accordance with the invention;

Figure 24 shows the heater of Figure 22 configured to pass flue products to a solar panel;

Figure 25 shows the heater of Figure 22 when in use;

Figures 26 to 29 show the heater of Figure 22 in various modes of operation;

Figure 30 shows a modification of the heater of Figure 22 to increase capacity;

Figure 30a is a schematic view of another modified water heater;

Figure 30b is a schematic view of another modified water heater;

Figure 31 shows typical plumbing connections for the heater shown in Figures 22 to 30;

Figures 32 to 34 show a modified heater in which the gas burner is replaced by one or more electric elements;

Figure 35 shows a preferred form of pre-heater tank;

Figure 36 shows a preferred form of pre-heater tank coupled for operating with hydronic fan coil units;

Figures 37 and 38 show a combined water heater storage tank unit;

Figure 39 shows a modified combined unit;

Figures 40 to 44 show details of a preferred form of solar elector panel;

Figures 45A, B, C and D show the way in which the solar panel is filled;

Figure 46 shows a further modified combined unit having an additional heat exchanger therein;

Figure 47 shows a further modified combined unit which is provided with an additional heat exchanger;

Figure 48 shows a further modified combined unit; and

Figure 49 shows a further modified combined unit which is provided with an additional heat exchanger.

Figure 1 is a diagrammatic representation of a water heater 2 constructed in accordance with the invention. The water heater 2 includes a hot water tank 4, gas burner assembly 6 and a flue pipe 8. The heater 2 includes a gas valve 10 which receives gas such as natural gas, town gas, propane or the like via gas line 12. Air for combustion is supplied by an air supply device 14 which may include one or more fans, as will be described later. The air supply device 14 receives air via an air input duct 16. Air from the air supply device 14 is supplied to the gas valve 10 via air line 18. A gas air inlet line 20 extends from the valve 10 to the burner assembly 6 for providing a combustible mixture of gas and air to the burner assembly. The gas valve 10 is preferably of a type which includes a venturi for introduction of gas from the gas line 12 into the air flowing therethrough, the arrangement being such that the more air which is supplied to the valve via the line 18 causes more gas to be entrained therein. The function is analogous to a carburettor of an

internal combustion engine. This ensures that the correct mixture of gas and air is supplied to the burner assembly 6 for efficient combustion. Valves of this type are known and therefore need not be described in more detail. One suitable valve is known as an Integrated Mixing System made by a European manufacturer, SIT Gas Control Systems.

The water heater 2 includes a flue control assembly 22 which is operable to control flow of flue gas from the flue pipe 8 to a flue outlet line 24.

Located within the hot water tank 4 is a heat transfer coil 26 (see Figure 2) having an outlet line 28, as shown in Figure 1. The coil 26 is preferably made from copper tubing able to withstand mains pressure water being coupled thereto. In use the tank 4 is filled with water and is heated by the burner assembly 6 which is substantially completely immersed in the water in the tank 4. Water to be heated is supplied by mains inlet line 32 which flows to a mixing valve 34 via mains inlet branch line 31 and then into the coil 26 via mains inlet branch line 33 where it is heated. The heated water returns to the mixing valve 34 via line 28. Hot water from the line 28 is mixed in the mixing valve 34 with cold water from the mains inlet line 32 so as to produce water on outlet line 36 at a predetermined temperature, say 45°C. This water can be used as a domestic water supply for bathrooms and the like. The heater includes a high temperature water outlet line 38 which is coupled to the line 28 to supply hot water directly out of the coil 26. This water is at a much higher temperature, say in the range 80°C to 95°C. This water is suitable for domestic use in a kitchen and/or laundry where higher temperatures are desirable.

The tank 4 and most of the other components of the water heater 2 are located within a sheet metal housing 40 and a layer of insulation 42 is located between the housing 40 and the tank 4, as shown.

In its simplest form, the water within the tank 4 is not circulated, heaters of this type being known as dead water heaters. It is possible, however, to circulate the water within the tank for room heating purposes. Accordingly, the water heater 2 of the invention includes a heating water outlet 44 which can be coupled to various elements of

an hydraulic heating system (not shown). The heater 2 includes a heating water return inlet 46 located near the bottom of the tank 4.

In the water heater of the invention, the water which is at mains pressure is confined essentially to the coil 26 and thus the tank 4 is not subjected to high pressures. The tank can therefore be made from relatively thin durable material such as copper sheeting or mild steel having a nominal thickness of say 1mm. The tank 4 should accordingly have a very long service life. The tank 4 may include a door 48 located near the bottom of the tank in order to provide access to the burner assembly 6 for servicing.

Figure 2 shows more details of the plumbing arrangement for the heater 2 in more detail.

It will be seen that the coil 26 includes a number of convolutions arranged in a generally frustoconical arrangement. It is preferred that the semi-apex angle A be in the range from 1° to 10°. This configuration has the advantage that when the burner assembly 6 is operating there will be upwardly directed convection currents as represented by arrows 49 (see Figure 4) above the burner assembly. Cold water flowing in the coil 26 will cause localised cooling of the water within the tank and so generate downwardly directed convection currents as represented by arrows 50 in Figure 4. The downwardly directed currents will be located between the coil 26 and the wall of the tank 4. Because the coil 26 tapers inwardly, the downwardly directed currents will be directed away from lowermost coils and this avoids cooling thereof and thereby enhances the overall heat transfer of the configuration. The coil 26 is preferably made from copper tubing having a nominal diameter of say 10mm to 15mm. Its length typically would be in the range from 20m to 30m and preferably about 25m. The coil could be formed as a single tube or two to four tubes of shorter lengths connected in parallel. It is envisaged that four tubes of about 6m each would be quite suitable because this would have less head loss as water passes through the heater 2.

The arrangement illustrated in Figure 2A includes a non-return valve 51 in the cold

water inlet line 32 and the line 33 is coupled to a pressure relief valve 52 before being inputted at the bottom of the coil 26 via water line 33 as shown. Inputting cold water at the bottom of the coil 26 ensures that the water emerging at the output line is hottest because the water in the tank 4 will tend to be hotter at the top of the tank than the bottom. The pressure relief valve 52 includes a pressure relief line 54 which opens into the top of the tank 4 and can discharge water harmlessly therein if the pressure is excessive. The tank 4 also includes an overflow line 56 which opens adjacent to the top of the tank. This eliminates unwanted pressure build-up within the tank 4 and tops up the water level in the tank 4.

Figure 2A shows a sterilised water storage tank 60 which is an optional feature of the heater. The tank 60 can be used to store only water which has attained a temperature which is sufficient for sterilising or substantially sterilising the water.. The arrangement can be such that when the water in the outlet line achieves a predetermined temperature, say 95°C, then that water can flow via sterilised water inlet line 62 to the sterilised water tank 60. A temperature sensing device 64 can be coupled to the line 28 to open a solenoid valve 66 when the temperature reaches the predetermined level. The tank 60 may include a ball valve 68 to ensure that the tank 60 does not overfill. Sterilised water can be drawn from the tank 60 via outlet line 70 when required for drinking and/or beverages.

Figure 2B shows a modified arrangement for the plumbing for the heater 2. This arrangement includes a small header tank 72 which effectively eliminates the air gap 75 which is present at the top of the tank 4 in the arrangement of Figure 2. The air gap 75 may cause corrosion problems if the tank 4 is made of material such as steel which is susceptible to corrosion. The tank 72 can be made from copper. The overflow line 56 from the tank 4 is U-shaped and opens into the top of the tank 72, as shown. A connecting line 74 connects the bottoms of the tanks 4 and 72. The tank 72 itself has an overflow line 76, the entrance of which is midway up the level of the tank, as shown. The provision of the lines 74 and 56 together with the positioning of the line 76, ensures that the water level in the tank 72 is above the top of the tank 4 and hence the tank 4 will always be completely filled with water. This thereby eliminates the air gap 75 and any corrosion problems which

may be associated therewith.

Figure 3 is a similar view to Figure 2B but diagrammatically shows that the header tank 72 can be located at a higher level which may be required in multi-storey applications. The pressure relief valve 52 is connected to the top of the tank 72 by the pressure relief line 54 as shown.

Figure 4A illustrates more details of the water heater 2. More particularly, Figure 4A shows the provision of an electric element 80 which is located within an element tube 82 so as to prevent water directly impinging on the element 80. The element 80 may, for instance, be a bobbin element of say 2.4 kilowatts. The outer end of the tube 82 is mounted in a port in the tank 4 and is accessible via the door 48 for servicing. The element 80 receives power from an electrical input conductor 84 which is connected to a relay 86. A first temperature sensor 88 which is mounted on the exterior of the tank 4 approximately midway up the tank or near the top of the tank. The sensor 88 is arranged to activate the relay 86 in order to supply current to the element 80 when the temperature at the sensor falls to or below a predetermined level, such as say 85°C. This would typically be required in periods of high demand when the gas burner assembly 6 is not able to maintain the correct operating temperature range within the tank 4. The electrical input conductor 84 includes a manual override switch 89 which allows the user to manually select a condition in which the electric element 80 is never operated. When the switch 89 is, however, turned on such as when there is an interruption to the gas supply, the heating element 80 can be operated, as described above.

In the arrangement of Figure 4A, the air supply device 14 includes first and second fans 90 and 92 for supplying air under pressure to the air inlet line 18 to the valve 10. In the illustrated arrangement, the fans 90 and 92 are of the same capacity but the first fan 90 is connected into the inlet line 18 via a branch line 94 which includes a flow restricting baffle 96. The branch line 94 may also include a bleed valve 98 which is arranged to discharge part of the air flowing from the fan 90. The arrangement is that in normal operation, a relatively low level of air is supplied to the valve 10 solely from the first fan

90. The relatively low level of air causes a proportionately low quantity of gas to be entrained in the air flow in the valve 10 and thus low levels of air gas mixture are supplied to the burner assembly 6. The proportions of gas in the mixture remain suitable for correct combustion but the relatively small flame ensures that good heat transfer occurs because of the relatively large dimensions of the burner assembly 6 (which is capable of handling significantly more air fuel mixture), as will be described below. The relatively low level of gas is suitable for maintaining the water temperature in the tank at the predetermined level such as in the range 90°C to 95°C. The water will remain at this level when there is low heat extraction caused by flow within the coil 26 and/or any hydronic heating elements connected to the water heater 2. A second temperature sensing element 100 is coupled to the water tank 4 for controlling operation of the fan 90 when the temperature falls below the predetermined level.

During periods of higher usage of the water heater, it is necessary to operate the gas burner assembly 6 at a higher level. To achieve this, a third temperature sensing element 102 is provided to sense when the temperature has fallen to a predetermined level, say 85°C. At this point the third sensor 102 is arranged to cause operation of the second fan 92. The second fan 92 causes a much higher rate of flow of air in the line 18 and hence a much greater quantity of gas air mixture for the burner assembly 6. By way of example, when the first fan 90 is operating alone, the burner assembly would have an output of say 10,000btu per hour whereas when the second fan 92 is operating, the output of the burner assembly may be typically 100,000btu per hour. The fans 90 and 92 may or may not operate simultaneously. Because the capacity of a second fan 92 is very much greater than that of the first fan 90, it does not make a great deal of difference if the first fan 90 comes into operation whilst the second fan 92 is operating. The first fan 90 preferably has a flow rate in the range from 5 to 10 cubic metres of air per hour and preferably about 6 cubic metres of air per hour. The second fan 92 preferably has a flow rate in the range from 90 to 150 cubic metres of air per hour and preferably about 105 cubic metres of air per hour.

In the water heater 2, the burner assembly 6 is only operated when required. Ignition of the gas-air mixture in the burner assembly could be accomplished by means of

a pilot light (not shown) in accordance with known principles. It is preferred, however, to use an electronic spark generator (not shown) for ignition. This could be coupled to the sensors 100 and 102 to cause ignition of the gas simultaneously with operation of the fans.

By having the first and second fans 90 and 92 the same, manufacturing costs can be lower because less inventory is required and other manufacturing efficiencies.

As mentioned previously, the water heater 2 includes a flue control assembly 22 which is arranged to effectively close the flue pipe 8 when neither of the fans 90 and 92 is operating. In the arrangement shown in Figure 4, this is achieved by mounting a cylindrical flue housing 104 on top of the tank 4, the housing 104 being arranged to receive the top of the flue pipe 8 and the bottom of the flue outlet line 24, as shown. A flue cover element 106 is located within the housing 104 and is normally seated on top of the flue pipe 8 in order to close it. The flue control assembly 22 includes a cylindrical locating sleeve 108 which surrounds the upper part of the flue pipe 8 and effectively prevents dislodgment of the flue cover element 106 from its position on the flue pipe 8. In the simplest form of the invention, the element 106 is held by gravity on the top of the pipe 8. It could, however, be biased by light springs or the like. It is envisaged that the element 106 may take the form of a flat disc of mild steel, say about 100mm to 120mm in diameter and having a weight in the range 40 grams to 100 grams.

When the fan 90 operates, there will be sufficient pressure in the flue pipe 8 to unseat the element 106 from the top of the flue pipe 8 and permit flue gases to escape through the flue outlet line 24. Typically the element 106 would need to be lifted from the flue pipe by a relatively small distance, say of the order of a millimetre to several millimetres, as illustrated diagrammatically in Figure 4B.

When the second fan 92, however, is operated it has a much larger capacity than the fan 90 and it will generate a higher rate of flow of flue gases in the flue pipe 8 and hence the element 106 will be lifted from the top of the pipe by a larger amount to accommodate the larger flow of flue gases. Typically the element 106 may be lifted by a

distance of about 20mm to 30mm when the second fan 92 is operating. The lower end of the flue outlet line 24 may include flue ports 107, as shown in Figure 4C. When the second fan 92 is operating it may cause the element 106 to engage the end of the flue outlet line 24. In this condition flue gases from the flue pipe 8 can enter the flue outlet line 24 via the flue ports 107. The arrangement has a substantial advantage in that when neither of the fans 90 or 92 is operating, the element 106 will be seated on the top of the flue pipe 8 and thereby effectively prevent heat losses from the water stored in the tank 4 caused by convection currents flowing through the flue pipe 8.

Figure 5 shows more details of the gas burner assembly 6. The gas burner assembly 6 has a housing 110 which is preferably made from mild steel sheet. The housing 110 includes a cylindrical sidewall 112, top wall 114 and bottom wall 116. The burner assembly includes an inlet coupling 118 to connect with the gas air inlet line 20. Located within the housing 110 is a gas burner element 120. In the illustrated arrangement, the gas burner element 120 preferably takes the form of a perforated stainless steel tube which at its near end is connected to the coupling 118 so as to receive the gas air mixture from the gas air line 20. The remote end 122 of the cylindrical element is closed. Typically, the cylinder would have a diameter of about 45mm and a length of say 200mm. As seen in Figure 5, the element 120 is located along a diameter of the cylindrical housing 110 and extends about half-way across the housing. The housing 110 includes a plurality of heat transfer tubes 124 which extend from the bottom wall 116 to the top wall 114. The tubes 124 are preferably made from mild steel and are open at the top and bottom and permit flow of the water in the tank therethrough by convection. This operates to create upwardly directed hot convection currents in the centre of the tank, as indicated by the arrows 49. As cooling occurs through heat transfer to the coil 26, downwardly directed convection currents will be located between the coil 26 and the wall of the tank 4, as indicated by the arrows 50. Mild steel can be used in the burner assembly 6 (as well as for the tank 4) because any oxygen dissolved in the heated water in the tank 4 will be quickly lost whereby corrosion rates will be very low.

The position and size of the tubes 124 can also be used to control the flow of

combustion products within the housing 110. In the arrangement illustrated in Figure 5, there are eight of the tubes 124, designated 124a, 124b, 124c, 124d, 124e, 124f, 124g and 124h. The tubes 124c, 124d, 124e and 124f are arranged in a closely spaced row between the end 122 of the gas element 120 and the flue pipe 8. This constitutes a restriction or barrier which tends to prevent flow directly from the gas element 120 to the flue pipe 8. The tubes 124a and 124b and the tubes 124g and 124h are spaced somewhat further apart so as to provide preferred flow paths for combustion gases between these tubes and the cylindrical sidewall 112 of the housing of the burner.. This enhances heat transfer to the water within the tank.

It will be appreciated by those skilled in the art that the water heater 2 described has many features which enhance the efficiency of operation thereof.

For domestic applications, typical specifications of the water heater are given by way of example only. These could, of course, be varied in accordance with the size of the unit:

low capacity of burner assembly 6	7,000 BTU/hr
maximum output of burner assembly 6	160,000 BTU/hr
flow rate of fan 90	$6m^3$ air/hr
flow rate of fan 92	$105m^3$ air/hr
volume of tank 4	150 litres
diameter of coil 26	400mm
length of coil 26	24 metres *
internal diameter of tube forming the coil 26	12mm
diameter of element 106	110mm
weight of element 106	60gm
operating temperature of first temperature sensor 88	70°C
operating temperature of second temperature sensor 100	96°C
operating temperature of third temperature sensor 102	85°C

* The total length of the coil 26 can be made up of a number of shorter lengths

connected in parallel.

As mentioned above, these values are given for the purpose of example only.

A modified heater 130 is illustrated in Figure 6. The same reference numerals will be used to denote parts which are the same as or correspond to the embodiment described in Figures 1 to 5. The water heater 130 illustrated in Figure 6 differs mainly from the arrangement shown in Figure 4 mainly in that a small capacity fan 132 is used in place of the first fan 90. This eliminates the need for the baffle 96 and the bleed valve 98. The airflow capacity of the fan 132 is a fraction of that of the fan 92, say one-tenth. The second temperature sensing element 100 is coupled to control the fan 132 and the third temperature sensing element 102 is coupled to control the fan 92. The operation of the water heater 130 is similar to that of the previous embodiment.

Figure 7A illustrates another modified water heater 140. This embodiment differs from the previous embodiment in that the two fans 90 and 92 are replaced by a single dual speed fan 142. Both of the temperature sensing elements 100 and 102 are coupled to the dual speed fan. The second temperature sensing element 100 is operable to cause low speed operation of the fan 142 and the third temperature sensing element 102 is operable to cause high speed operation of the fan 142. The difference between low speed and high speed operation of the fan 142 is such that the flow rate at high speed is about ten times that of the flow rate at low speed. Again the operation of the water heater 140 is analogous to that of the previous embodiments.

Figure 7B shows an alternative arrangement which uses only the second fan 92 (which is of the higher capacity) but it is arranged to be operated at a low rate by selectively supplying it through a series resistance which reduces the power thereof. Figure 7B shows an electrical input conductor 141 coupled to the fan 92 via a series resistance 144. The circuitry includes first and second relays 145 and 146 having normally open contacts 147 and 148 respectively. The second and third temperature sensing elements 100 and 102 are coupled to the relays 145 and 146 respectively. When the

temperature at the element 100 reaches say 96°C, it operates the first relay 145 and its contacts 147 close. This enables the supply of electricity through the electrical input conductor 142 via the series resistance 144. The value of the resistance 144 is such that most of the voltage drop is across the resistance rather than in the coil of the fan 92. Consequently, the fan 92 will be operated at a relatively low level, as required. If the temperature in the tank falls to the third predetermined level, say 85°C, the third element 102 will cause the second relay 146 to close its contacts 148. This effectively bypasses the resistance 144 and the full power available from the electric supply will be available to the fan 92 which will then operate at full power, as required. The circuitry shown in Figure 7B has the advantage that with the provision of suitable relays and a resistance 144, an alternating current fan can be used for the fan 92 without the need for expensive speed control techniques which typically need DC fans and the like.

In this arrangement, it is also possible to control the operation of the solenoid valve 66, as shown in Figure 2A, by having it coupled to additional, normally closed contacts of the relay 145, as will be described later. This eliminates the need for a separate temperature sensing device 64.

The dual control arrangement illustrated in Figure 7B can be accomplished by utilising a motor (not shown) which has a tapped coil thereby enabling part or the whole of the coil to be selectively excited in order to have its operating speed run at a low or full speed. The sensors 100 and 102 could be used to control applied voltages to the tapped coil of the motor.

Figure 8 illustrates another modified water heater 150. This embodiment includes a single speed fan 152 which is coupled to the second temperature sensing element 100 in order to control the ON-OFF operation thereof. A modified flue control assembly 153 in this arrangement is different from that of the previous embodiments and is the main way in which the heating output of the burner assembly 6 is varied. In this arrangement the sensing element 100 operates to turn the fan 152 ON when the temperature of the water within the tank 4 falls to a predetermined level, say 95°C. In this condition, the burner

assembly 6 operates at a relatively low output. This is caused by restriction of the flow of gases in the flue pipe 8. In this arrangement, the flue cover element 106 is slidably mounted on a support shaft 154. The shaft 154 is provided with upper and lower stops 156 and 157. The shaft 154 is itself pivotally connected to a control lever 158, the position of which is controlled by means of a solenoid actuator 160. The solenoid actuator 160 is coupled to the third temperature sensor 102. The modified flue control assembly 153 includes a return spring 161 which acts on the opposite end of the lever 158 and tends to bias the lever 158 into the position in which it is shown in Figure 8.

The operation of the modified flue control assembly 153 is as follows. When the temperature of the water in the tank 4 is above a predetermined level, say 95°C, both of the temperature sensing elements 100 and 102 will be deactivated. In this position, the flue cover element 106 will be seated on top of the flue pipe 8 and hence will prevent flow of convection currents therethrough. When, however, the temperature of the water within the tank 4 falls below the predetermined level, the second temperature sensing element 100 will cause operation of the fan 152. This generates sufficient pressure for the element 102 to lift from the top of the flue pipe 8 by a small amount. The element 106 can have a limited sliding movement on the shaft 154. A sliding movement in the range of say 1mm to 5mm would be sufficient for this purpose because only a small flow is required in order to determine that only a small quantity of gas is burnt in the burner assembly 6. When, however, the temperature of the water within the tank 4 falls to a second predetermined temperature level of say 85°C, the third temperature sensing element 102 will cause operation of the solenoid actuator 160. This produces an anti-clockwise rotation of the lever 158 (as seen in Figure 8) so that the shaft 154 will lift the element 106 clear of the top of the flue pipe 8. The element 106 is retained on the shaft 154 between the stops 156 and 157. Once the element 106 has been lifted clear of the top of the flue pipe 8, the restriction on flue flow is removed and significantly more air gas mixture will be blown into the burner assembly 6 for increased gas combustion therein. Again, the rate of energy input in the standby mode (when the sensing element 100 is operated) is only a small fraction, say one-tenth, of the energy consumption compared to the high rate (when the sensing element 102 is operated). The operation of the heater 150 is otherwise similar to

that of the previous embodiments.

If the water heater 2, 130, 140 or 150 is subjected to high loads through hot water and/or hydronic heating, the temperature will fall to a third predetermined level, say 85°C. When this occurs the first sensor 88 will operate to turn the element 80 on to provide additional heating capacity . In this mode the operation of the heater is analogous to that of an instantaneous water heater so that in most domestic applications the hot water supply would not run out. It will also be appreciated that if the gas supply is interrupted then it is possible to have at least some hot water available because of the provision of the element 80. Similarly, if the mains supply is restricted then hot water would still be available because the heater can operate on gas as the main power source for heating the water.

In the embodiments described above, the sensors 88, 100 and 102 can be used to control the operation of relays. It is however possible to utilise sensors which include biometallically controlled contacts. Sensors of this type are available which are rated up to 20 amps and therefore these sensors can be connected directly in series with the supply voltage. Accordingly, when the contacts of such sensors close they can directly cause operation of the fans 90, 92, 132 or 142 and/or the element 80.

Figure 9A diagrammatically illustrates a gas solar heating system 170 of the invention. The system includes a water heater 2 which can be of the type illustrated in Figures 1 to 5. Alternatively, it could be of the modified forms of water heater 130, 140 or 150, as shown in Figures 6, 7 and 8. The system 170 includes a solar absorber panel 172 and a solar pre-heating tank 174. Generally speaking, solar energy absorbed by the absorber panel 172 is stored as heated water in the tank 174. The tank 174 serves as a preheater for cold water supplied to the water heater 2. The solar preheating for the water heater 2 results in substantially decreased need for operation of the gas burner assembly 6 and hence much less gas is required because of the solar energy input. As will also be described in more detail below, heat energy in the flue gases can also be coupled to the absorber panel 172 in order to extract heat therefrom. This again increases the overall efficiency of the system.

The solar tank 174 is not subjected to water under high pressure nor is it subjected to water at a very high temperature because the absorber panel 172 is not of a concentrating type. The maximum temperature of the water within the tank 174 is unlikely to normally exceed about 60°C to 70°C. The tank 174 can therefore be made from plastics material or other relatively cheap materials. The tank 174 has an outlet 176 near its bottom connected to a supply line 178 which includes a water pump 180. The supply line 178 extends to the top of the panel 172 and water therefrom is introduced into the top of the panel 172. The system includes a return line 182 from the bottom of the panel 172 to the top of the tank 174, as shown. The panel 172 includes a temperature sensor 184 and the bottom of the tank 174 includes a further water temperature sensor 186. The arrangement is such that when the temperature sensed by the sensor 184 in the panel 172 is higher than the temperature sensed by the sensor 186 at the bottom of the tank 174, the pump 180 is operated. The control circuitry (not shown) for the pump 180 is coupled to the control circuitry for the water heater 2, the arrangement being such that when the pump 180 is to be operated, it is arranged to be operated before any of the fans 90, 92, 132 or 152 is operated so that the panel 172 will have water from the tank 174 circulating therethrough before flue gases from the line 24 are passed through the absorber panel 172. This ensures that the panel 172 is not damaged by overheating which may be caused by the flue gases. This causes a circulation of water through the panel 172 where it is heated by solar radiation. The control is such that circulation will stop when a condition is sensed that the temperature within the tank 174 is higher than that being produced in the panel 172. This effectively prevents unwanted heat loss from the panel 172 at night or at times of low solar radiation intensity. The arrangement of the circulation system between the panel 172 and the tank 174 is such that when the water pump 180 is not operated, all water drains back into the tank 174. This avoids problems which might otherwise be caused by freezing of water within the panel which can sometimes occur where the system is used in cold climates. The tank 174 includes an overflow 188 which can discharge excess water from the tank 174 in the event that it becomes overfilled.

As mentioned above, the tank 174 is essentially used as a pre-heater for the cold

water supplied to the water heater 2. This is achieved by arranging for cold water from the mains inlet line 32 to pass via mains branch line 33 to a heat transfer coil 190 located in the top of the tank 174. The coil 190 has an outlet line 192 which is coupled to the cold water inlet of the coil 26 via the pressure relief valve 52. The valves 51 and 52 may be combined in a single fitting of known type. The outlet line 192 is thus coupled to the input of the combined non-return and relief top up valve 51, 52 of Figure 2A.

In an alternative arrangement, the water heater 2 could be replaced by a conventional mains pressure hot water system. In this arrangement, the absorber panel 172 and pre-heating tank 174 could be used as a pre-heater for mains pressure water which is supplied to the mains pressure water heater. This would of course result in increased overall efficiency. In addition, the heated water in the tank 174 could be circulated through an hydropic heating system (not shown).

The system 170 illustrated in Figure 9A also includes another feature which enhances efficiency. More particularly, the overflow line 56 from the tank 4 is coupled to the top of the tank 174. This ensures that any heat contained in the overflow water is not lost to waste but rather is added to the energy stored in the water in the solar tank 174. This also ensures that the water level in the tank 174 is topped up. It will also be seen that the top of the tank 174 is at a lower level than the top of the tank 4 so as to ensure that water from the solar tank 174 does not pass to the tank 4.

A further energy saving feature is incorporated into the system 170 shown in Figure 9A. This concerns the utilisation of heat energy in flue gases which are in the flue outlet line 24. The panel 172 includes a heat exchanger 194 which is arranged to transfer heat from the flue gases to the water which is circulating through the panel 172. The heat exchanger 194 has an inlet 196 which is coupled to the flue line 24 and an outlet 198 which is connected to a balanced flue fitting 200. The air input duct 16 is also coupled to the balanced flue fitting 200 so that the burner assembly 6 can operate reliably in various wind conditions in the usual way. It is possible, however, that the air inlet duct 16 may not be required and a simple cowl (not shown) is used instead of the balance flue 200. Such an

arrangement may be possible because when the gas burner assembly 6 is operated, one or other of the fans will be operating thereby the flue gases will be at a positive pressure and hence will be less susceptible to blow back caused by wind.

Figure 9B schematically illustrates a simplified control circuit for the system shown in Figure 9A. In this arrangement, by way of example, includes the single fan 92 configured as described in relation to Figure 7B. It will be appreciated that similar arrangements are applicable to the other modified versions of the system.

Electric power is supplied via electric conductor 141 to the solenoid valve 66, fan 92, element 80 and pump 180, as shown. The temperature sensing element 100 is connected to the relay 145 via a delay element 191. The delay element 191 could be electronic or mechanical and is arranged to produce a delay of a predetermined period, say 30 seconds to a minute from the time the preset temperature of the element 100 is sensed to the time in which the relay 145 operates. This enables the pump 180 to be operated so that water is circulated through the panel 172 prior to operation of the burner assembly 6, as mentioned above. In the illustrated arrangement, the relay 145 has a second pair of contacts 193 operated thereby. The contacts 193 are of a normally closed type and these are connected in series with the electrical supply line to the solenoid valve 66. The arrangement is such that only when the temperature in the tank 4 is above the predetermined temperature, say 96°C, of the sensing element 100 will power be available to the solenoid valve 66. Thus, only water heated to this temperature can be supplied to the sterile water storage tank 60 via the ball valve 68.

The circuit also shows the normally open contacts 147 which are coupled in the electric supply to the fan 92. The resistance 144 is also connected in series with the supply but that can be bypassed by the contacts 148 operated by the relay 146 when the second predetermined temperature, say 86°C, is sensed by the sensing element 102. This enables full operation of the fan 92, as described previously.

Figure 9B also shows the sensor 88 coupled to the relay 86 which has normally

open contacts in series with the electric conductor to the element 80, the override switch 89 being also connected in series therewith, as described previously.

The circuit shows the sensors 184 and 186 coupled to the input of a comparator 197, the output of which is used to control a relay 199 having contacts 201. The contacts 201 are connected in series with the electric supply conductors to the pump 180. The arrangement is such that the circulating pump 180 is only operated when the temperature of the water within the panel 172 is greater than that of the water in the bottom of the tank 174 by a predetermined amount, say 2 to 10°C. This function, however, can be overridden when it is necessary to operate the heater 2 and it is desirable to operate the pump 180 prior to operation of the burner assembly 6 so that the panel 172 is not overheated. This can be arranged by coupling output from the sensing element 100 via sensing line 203 to a first input of an OR gate 205. The second input to the OR gate 205 is coupled to the output of the comparator 197. The output 207 from the OR gate is coupled to the input of the relay 199. This arrangement ensures that the pump 180 is operated a predetermined period, as determined by the delay element 191, prior to operation of the fan 92 and hence the burner assembly 6 of the water heater 2.

Figure 10 schematically shows more details of the solar pre-heating tank 174. It includes a cylindrical sidewall 202 and top and bottom walls 204 and 206. The bottom wall 206 could be moulded integrally with the sidewall 202 or alternatively could be bonded thereto. The top wall 204 includes inlet fittings 177 and 179 for coupling to the return line 182 and overflow line 56 respectively. The capacity of the tank 174 can be varied according to circumstances. It is thought, however, that the volume of the tank 174 would be about 150 litres where the system 170 is to be used for domestic purposes. The coil 190 is subjected to water at mains pressure and accordingly would normally be copper tubing having a diameter in the range from 10mm to 15mm. Typically the length would be 25 metres.

Figures 11A and 11B illustrate in more detail the solar absorber panel 172. The solar absorber panel 172 includes a framework 220 which is preferably formed from

aluminium C-sections 222. In the illustrated arrangement, the C-sections form a rectangular framework which supports a base 224 formed of insulating material, as shown in Figure 12. The base 224 is formed with longitudinally extending corrugations upon which a layer 225 of solar energy absorptive material is laid. The layer 225 preferably comprises black plastics material such as polypropylene. The panel 172 includes a sheet 226 of transparent material such as acrylic sheet which is also corrugated and which conforms generally to the shape of the corrugations in the absorptive layer 225. This defines a water passage 228 through which water from the pump 180 and supply line 178 is circulated. The top layer of the panel 172 is formed by a transparent corrugated sheet 230 which defines an air gap 232. The air gap 232 helps to minimise heat losses which might otherwise be caused by heat conduction to wind or air currents or the like passing over the absorber panel 172. The supply line 178 may be coupled to an inlet distributor manifold (not shown) to help to assist uniform distribution of the heat transfer water across the face of the panel 172. Similarly, a collection manifold (not shown) may be provided at the lower end of the panel 172 for collection of the water for admission to the return line 182.

As mentioned previously, the panel 172 includes a heat exchanger 194 for extraction of the heat values of flue gases flowing in the flue outlet line 24. More particularly, the heat exchanger 194 includes an inlet manifold 240 which is connected to a plurality of longitudinally extending heat transfer tubes 242 which are located between the insulating base 224 and the heat transfer layer 225. The upper ends of the tubes 242 are connected to an outlet manifold 243 which is, in turn, connected to the outlet 198. In use, flue gases from the flue outlet line 24 transfer heat to the water which is being circulated through the absorber panel 172. After emerging from the panel 172, the flue gases pass to the balanced flue fitting 200, as shown in Figure 9.

It will be appreciated by those skilled in the art that the system shown in Figure 9 incorporates a number of novel features which enhance the overall efficiency thereof.

Figures 12A and 12B illustrate a modified form of absorber panel 244. In these

drawings, the same reference numerals have been used to denote parts which are the same as or correspond to those of the panel which is shown in Figures 11A and 11B. In this arrangement, the insulating base 224 is flat and located on it is a stainless steel envelope 245 having the inlet 196 and outlet 198 for the flue gases. In this arrangement, the solar absorptive layer 225 preferably comprises a layer of black paint applied directly on the upper surface of the envelope 245. A layer 246 of water from the inlet supply line 178 flows over the layer 225 so as to absorb solar energy. Water flows under gravity down the panel and then is discharged from the water outlet to the return line 182. A glass sheet 247 forms the top of the panel and an air gap 248 is maintained between the layer 246 of water and the glass sheet 247 in order to minimise heat losses through conduction through the glass sheet 247.

Figures 13 and 14 illustrate a modified gas-solar system 250 which is similar to the arrangement shown in Figures 9 to 12. The essential difference between the system 250 and the system 170 is that, in the system 250, the flue gases in the flue outlet line are arranged to bubble directly through the water which circulates through the absorber panel 172. This can be achieved readily by arranging for the flue outlet line 24 to be coupled to an inlet duct portion 252 which is at a higher level than the absorber panel 172. This arrangement prevents unwanted flow of the circulating water from the solar absorber panel 172 flowing into the flue outlet line 24. In the absorber panel 172, the heat transfer tubes 242 are not required because the inlet manifold 240 can be arranged to supply the flue gases directly into the water passage 228. The flue gases bubble through the water and emerge at the outlet 198 which also serves as the input to the return line 182. The outlet 198 is coupled to the balanced flue fitting 200, as before. The passage of the flue gases directly through the circulating water in the solar absorber panel very significantly enhances utilisation of the heat in the flue gases. Also, the water will tend to absorb pollutants in the flue gases so that they can be collected in the water in the tank 174. The water in the tank 174 is gradually changed over a period of time because of the periodic top up from line 56 and discharge from overflow 188. Figure 14 diagrammatically shows the upper level 254 of water in the inlet duct portion 252 when the air supply device 14 is not operating. Basically, the arrangement is such that water from the solar absorber panel

172 and tank 174 cannot normally pass to the water heater 2 because the portion 252 is at a higher level than the panel 172.

Figures 15A and 15B diagrammatically illustrate a modified gas-solar system 260. This arrangement is similar to that shown in Figures 13 and 14 except that the solar absorber panel 172 is disposed in a vertical orientation which may be necessary in some applications. In this arrangement, the inlet duct portion 252 is disposed in a position where it is higher than the outlet 198 of the panel 172 so as to prevent flow of water from the panel 172 to the water heater 2 via the flue line 24. Figure 15A shows diagrammatically the water levels in the absorber panel 172 when the gas burner assembly 6 of the water heater 2 is operating. Figure 15B diagrammatically shows the water levels when the gas burner assembly 6 is not operating. It will be seen that because of the position of the inlet duct portion 252, water flow from the absorber panel 172 to the heater 2 is prevented.

Figure 16A is a fragmentary view of part of the system shown in Figures 15A and 15B showing a modification thereof. In particular, the flue gas outlet 198 from the panel 172 has a supplementary inlet line 262 coupled thereto. Inlet line 262 includes a fan 264. The supplementary inlet line 262 and fan 264 may be required in order to enable satisfactory operation of the system where the panel 172 is disposed in a vertical orientation. More particularly, the fan 264 can be of a high capacity type which produces a relatively large flow of air therethrough which therefore tends to entrain flue gases which have passed through the panel 172 into the air stream generated by the fan 264 for input to the balanced flue 200.

Figure 16B shows a further modification. In this arrangement the fan 264 is connected directly in the outlet 198 to enhance flow therethrough. The fan 264 again can be a high capacity type. It is arranged so that it is turned on when any of the other fans of the water heater are on.

Figure 17 diagrammatically illustrates a modified system 270 in accordance with a further aspect of the invention. This arrangement is generally similar to that shown in

Figures 14, 15A and 15B but the system includes an internal combustion engine 272 which is coupled to an electric generator 274. The generator 274 is arranged to charge batteries 276. The batteries can be used for powering various electrical appliances which are arranged to operate on DC. Alternatively, the batteries 276 could be coupled via an inverter so as to produce 240 volts AC whereby normal domestic electric appliances could be operated.

The internal combustion engine 272 has an exhaust 278 which is coupled via an exhaust line 290 to the solar absorber panel 172. It is preferred that the exhaust line 290 is connected into the inlet duct portion 252 which is used to convey flue gases from the burner to the solar absorber panel. The preferred way of connecting the flue outlet line 24 to the exhaust line 290 is by forming a venturi 279 in the exhaust line 290 and arranging for the end of the flue outlet line 24 to be located in the venturi 279. The exhaust gases flowing in the line 290 will generally be at a higher pressure and flow rate than the flue products in the line 24 and by having the venturi coupling, the exhaust gases will tend entrain the flue products into the larger flow and then into the panel 172. In this way heat energy in the exhaust gases from the internal combustion engine can also be collected by water circulating in the absorber panel 172. This arrangement provides for efficient utilisation of the fuel used for the burner assembly 6 as well as the internal combustion engine 272. The system 270 could be advantageously used in remote locations to provide combined electric power, hot water and heating services. The internal combustion engine 272 can also be used to operate on the same gas source which is used for the water heater 2. It will be further appreciated that the system 270 avoids transmission losses which can be significant in normal electricity distribution systems. Pollution is minimised because the flue gases from the burner assembly 6 and exhaust gases from the engine 272 bubble through the water circulating in the panel 172 and at least some of the pollutants will remain in the water.

Figures 18A and 18B show a modified gas-solar system 300 which is similar to that shown in Figures 15A and 15B as well as the header tank arrangements which are shown in Figures 2B and 3. The same reference numerals will be used to denote parts which are

the same or correspond to one another.

The modified gas-solar system 300 shown in Figures 18A and 18B includes a dual header tank unit 302. The unit 302 includes a header tank 72 which is coupled to the heater 2 and functions in the same way as the header tank 72 described in relation to Figure 3 above. The outlet line 76 however is coupled to the top of a second header tank 304 which is located beneath the header tank 72. The second header tank 304 serves to ensure that the solar pre-heating tank 174 is always full of water and that water therefrom does not flow back to the heater 2. The overflow line 188 from the solar pre-heating tank 174 is connected to the top of the second tank 304, as shown. A connecting line 306 extends from the bottom of the tank 304 to the bottom of the tank 174. The second header tank 304 has an overflow line 308 which has its top located about midway in the tank 304. When the level of water within the tank 304 goes above the level of the inlet to line 308 it is bypassed through that line to waste. In multi-storey applications, the dual header tank unit 302 is preferably located at a position where the middle of the tank 304 is no lower than midway along the level of the solar absorber panel 172, as indicated by broken line 310 in Figure 18A. This ensures that when the heater 2 is not operating, the water from the absorber panel 172 does not flow back to the heater 2 because of the water trap effect of the inlet duct portion 252, as in the case of Figure 15A. Also, the static water level of the water which is circulated to the absorber panel 172, will be approximately midway along the length of the panel 172 and therefore the circulating pump 180 need only be of small capacity and does not need to be a high pressure pump in order to generate enough pressure to lift the water along the supply line 178 to the absorber panel 172. Consequently, the pump 180 can be of relatively low capacity and need not operate under high pressure.

Figure 18B shows the system 300 when the heater 2 is operating. In this configuration, flue gases are flowing in the flue outlet line 24 to the panel and the flue gases will bubble or flow through the panel 172 so that useful heat can be extracted therefrom into the circulating water through the panel 172. The pump 180 is operating so that water fills the absorber panel 172 up to the level indicated by broken line 312 up to the

level of its outlet, as indicated by line 312. Thus it will be appreciated that the pump 180 need only generate sufficient head equivalent to the distance in height between the lines 310 and 312 and frictional head losses. It will also be noted that the inlet duct portion 252 is above the lines 310 and 312 and therefore water does not flow from the absorber panel 172 back to the heater 2.

The dual header tank assembly 302 can be made as a compact integrated unit which facilitates installation thereof in multi-storey applications.

Figure 19 shows the system 300 illustrated in Figures 18A and 18B incorporating a junction and joining box 314. The junction and joining box 314 can be supplied as an assembly of couplings mounted on a framework or the like which can be used for coupling together the various ducts and water lines of the system. This facilitates installation thereof, particularly in multi-storey applications. In the illustrated arrangement, the junction and joining box 314 can be used for forming junctions in the system. In the illustrated arrangement, this would include the air inlet duct 16, overflow line 56, pressure relief line 54, connecting line 74, overflow line 308, connecting line 306, overflow line 188, flue outlet line 24, return line 182 and supply line 178.

Figure 20 shows another modification of the system shown in Figures 18A and 18B. In this arrangement, the pressure relief valve 52 is located in the pressure relief line 54 which is inputted to the first header tank 72 of the dual header tank unit 302, as shown. By locating the pressure relief valve in the pressure relief line 54 ensures that it is operating with cold water rather than with hot water as it does in the arrangement of Figures 18A and 18B. The pressure relief valve 52 will therefore have a longer life because it operates only with cold water in the arrangement of Figure 20.

Figure 21 illustrates another modified gas-solar system 340. It is similar to the system shown in Figures 18A and 18B except that the panel 172 is orientated in an inclined plane, as in the arrangement illustrated in Figure 9. In this arrangement, the dual header tank unit 302 is located above the level of the absorber panel 172. More

particularly, the overflow line 308 of the second header tank 304 has a level indicated by broken line 342. It will be seen that this is higher than the level of the return line 182, as indicated by the broken line 312. This arrangement has the advantage that because the panel 172 is always full of its circulating water, the pump 180 does not need to be operated prior to operation of the heater 2 which might otherwise cause overheating of the components of the panel 172. It also decreases the operating requirements on the pump 180.

Figures 22 to 29 illustrate a modified form of hot water heater which is similar to the previous embodiments. The same reference numerals have been used to denote parts which are the same as or correspond to those of the previous embodiments. In the embodiment shown in Figures 22 to 27, the hot water heater is arranged for stand alone operation for supplying domestic hot water. In the arrangement shown in Figures 28 and 29, the water heater is configured for dual hot water and space heating operations. In these Figures some of the components have been omitted for clarity of illustration.

In this embodiment, the hot water tank 4 is cylindrical. The sheet metal housing 40 includes a cylindrical part 41, the insulation 42 being sandwiched between it and the hot water tank 4. The housing also includes a rectangular part 43 which is spaced from the cylindrical part 41 so as to define the air input duct 16, as best seen in Figures 22 and 23. The housing 40 includes a top 47 and bottom 53, feet 55 being provided beneath the bottom 53. The rectangular part 43 may include vents 45 for admitting air into the air input duct 16. Other components and fittings can conveniently be located in the space between the tank 4 and the rectangular part 43.

The dual speed fan 142 is mounted adjacent to the gas valve 10 so that the gas valve 10 supplies gas directly into the inlet of the fan so that the gas is mixed with the air and then passes to the gas air inlet line 20 which also extends in the space between the housing parts 41 and 43. In this embodiment, the pressure release valve 52 is connected into the sidewall of the tank 4 adjacent to the gas burner assembly 6. It is normally set to relieve pressure within the tank when the pressure exceeds a predetermined level, say three

atmospheres, so as to avoid excessive pressures being built up within the tank.

The hot water tank 4 also includes a fill and drain fitting 57 adjacent to the bottom 39 which is normally closed by a cap or the like (not shown). The fitting 57 can be used for initial filling of the hot water tank 4 and for draining the tank 4 when the heater needs to be moved or serviced.

The tank 4 also includes a level indicator fitting 59 which is located just below the top 61 of the tank 4. The level indicator fitting 59 is normally closed by a cap (not shown). When the tank 4 is being filled, the cap can be removed so that the installer of the heater can fill the water up to the level of the indicator fitting 59 so as to define a predetermined air gap 75, as shown in broken lines in Figure 22. After initial filling of the tank 4, the fittings 57 and 59 are capped or plugged and the water therein remains in the tank permanently, during normal operation. This eliminates the need for a header tank or the like to replenish water within the tank 4. Thermal expansion and contraction of the water within the tank 4 is accommodated by compression of the air within the air gap 75. Typically, the volume of air in the air gap 75 is sufficient that at maximum expansion of the water the pressure within the tank is 1.5 atmospheres. Normally the volume of air in the air gap to the total volume of the tank is in the range 3 to 10% and preferably 5%. It will be appreciated that the normal operating pressure of 1.5 atmospheres is substantially less than mains water pressure and therefore the tank 4 does not need to be a pressure vessel as in the case of mains pressure hot water services.

The tank 4 may include a sacrificial element 63 connected to the top 61 of the tank so as to react with oxygen in the air gap 75 and reduce corrosion of the tank. The sacrificial element 63 may be made of magnesium or aluminium.

The mains inlet line 32 and outlet lines 36 and 38 pass through the rectangular part 43 of the housing so that the lines can then extend within the rectangular housing part 43 so that they can then be coupled into the top 61 of the tank. The heating water outlet 44 and heating water return inlet 46 are located in the sidewall of the tank 4 and pass directly

through the cylindrical part 41 of the housing. It will be noted that the mixing valve 34 is located above the insulation on the top 61 of the tank. The inlet line 33 to the coil 26 passes through the top 61 of the tank. The outlet line 28 from the coil 26 also passes through the top 61 of the tank. This provides for a compact assembly and convenient location of the mixing valve 34 on the top of the tank.

In this embodiment the coil 26 is again spirally wound. This enhances heat transfer by promoting creation of convection currents within the tank as cold water is introduced into the coil 26. Typically the apex angle of the coil 26 is in the range 0 to 10°. The coil 26 is supported within the tank 4 by means of radially extending upper and lower support arms 77 and 78. The arms may be formed from mild steel rod and provided with rubber or plastic grommets on their outer ends which engage the inner surface of the tank 4. In this embodiment the coil 26 is about 18 metres long and formed from copper tube having a nominal diameter of 20mm.

In this embodiment, a balanced flue 79 is mounted directly on the top 47 of the housing and the flue control assembly 22 is mounted therein, as shown. The flue 79 includes outlet vents 81. In this embodiment, the flue control assembly 22 takes the form of a flue dampening vane 83 which is mounted on a horizontal pivot 85 within the flue 79. The vane 83 is balanced so that it normally closes the flue pipe 8 by gravity but increased pressure within the flue pipe 8 caused by combustion gases causes the vane 83 to lift off and enable escape of exhaust products through the vents 81. When the burner assembly 6 is not operating, heat losses caused by convection currents within the flue pipe 8 are avoided because the vane 83 effectively closes the flue pipe 8.

In this embodiment, the gas burner assembly 6 is somewhat deeper than that described in the previous embodiments and extends for about 40% of the length of the tank 4 in order to provide a greater surface area for the heat transfer tubes 124, thereby enhancing heat transfer to the water within the tank. As best shown in Figure 23, there are twenty heat transfer tubes 124 in the burner assembly each having a diameter of about 50mm and a length of about 400mm.

Figure 24 illustrates a modified form of heater which is similar to the heater shown in Figures 22 and 23 except that the flue 79 is connected to the flue outlet line 24 so that heat within the flue gases can be collected in solar absorbing panels, as in the previous embodiments. In this arrangement, the flue 79 includes a blocking plate 87 which is held within the flue 79 by brackets 91 so as to effectively prevent escape of flue gases through the vents 81 and direct them into the flue outlet line 24.

Figure 25 diagrammatically shows a further modification of the water heater. In this arrangement, a number of reinforcing rods 93 extend longitudinally through the tank. The ends of the rods 93 are connected by welding of the like to the top 61 and bottom 39 of the tank. The reinforcing rods help prevent buckling of the top and bottom of the tank when there is above atmospheric pressure therein. Preferably there are four of the rods 93, each of which may be formed from mild steel rod having a nominal thickness of say 12mm. The rods can pass through the tubes 124 as diagrammatically illustrated in Figures 23 and 25.

Figures 26 to 30 illustrate diagrammatically the way in which the water heater can be installed and used in various modes of use.

Figure 26 diagrammatically shows the water heater being set up for stand alone supply of domestic hot water without space heating. The drawing also shows the preferred location of the various temperature sensing elements. More particularly, Figure 26 shows the first, second and third temperature sensing elements 88, 100 and 102 being mounted on tubes which extend through the top 61 of the tank and into the water in the tank, i.e. below the maximum air gap 75 which is determined by the open level indicator fitting 59. As in previous embodiments, the temperature sensor 88 controls the electric element 80 and the second and third temperature sensing elements 100 and 102 control the operation of the dual speed fan 142, as before. Preferably the temperature sensing elements may be of known type such as capillary or surface mounted thermostats.

Figure 26 diagrammatically represents the condition in which the tank 4 has been initially filled with cold water up to the level of the level indicator fitting 59. A supply of cold water is connected to the fitting 57 and the tank filled up to the level of the level indicator fitting 59 and thereafter the fitting 57 is closed. The air gap 75 is at its maximum volume and the pressure within the air pressure of the air gap 75 is atmospheric pressure. In this condition the vane 83 is closed because the fan 142 is not operating.

Figure 27 diagrammatically illustrates the condition of the heater as it first heats up. It will be seen that both the fittings 57 and 59 are now closed. Assuming that the initial temperature of the water admitted to the tank 4 is about 15°, when the burner assembly 6 is operated and the water within the tank 4 is heated up to a temperature within the range 80°C to 100°C, expansion of the water will cause an increase in pressure in the air gap between about 7 and 8 psi (above atmospheric) caused by expansion of the water and consequent reduction of the volume of the air gap. Convection currents will begin to flow within the water in the tank, as indicated. The initial setting of pressure in the tanks is only increased by the heating of the water after the level indicator has been plugged.

The tank air gap pressure absorption principle allows the installer to set different pressure settings in the tank. If the level indicator fitting is unplugged and open to atmosphere whilst the tank water is being heated, the pressure setting of the tank will be directly related to the temperature of the tank water when the level indicator is plugged. If the tank water is heated up to the units thermostatically preset temperature and then sealed the tank will be at atmospheric pressure, and should the tank water drop in temperature through normal operation the tank pressure will reduce below atmospheric pressure creating a vacuum.

In the arrangements of Figures 26 and 27 the water unit is used solely for providing hot water at the hot water outlet lines 36 and 38. Accordingly, the heating water outlet 44 and heating water return inlet 46 are plugged, as shown.

Figure 28 shows the heater connected for providing hot water as well as for

hydronic heating. More particularly, hot water is available on the outlet lines 36 and 38, as before. The heating outlet 44 and return inlet 46 are connected to lines which extend to various hydronic heating devices (not shown) such as panels which may be located at a level above the tank. In this case it is necessary to initially fill the tank 4 so that it is initially at a pressure above atmospheric. To achieve this, mains water is coupled to the fitting 57 via a pressure control valve 95 which controls the pressure of water admitted to the tank 4. Normally the valve 95 does not form part of the unit and is an accessory which is provided when required. In this case the level indicating fitting is closed and water fills the tank 4 and passes to the various hydronic heating panels (not shown) through the outlet 44. Air from the hydronic heating panels may be bled in the usual way. Filling continues until the pressure of air within the air gap 75 is about 15 psi. This would normally correspond to a position in which the level of the water is about 40mm above the level of the level indicator fitting 59.

Figure 29 shows the water heater configured for providing hot water and for space heating through hydronic fan coil heating units (not shown). The volume of water and the pressure in the water tank required to service a fan coil is less than what is required to service traditional water heating panels mounted above the unit. The tank air gap pressure absorption principle set at a lower setting for fan coil delivery allows the unit to supply water to the fan coil positioned above the heater on a flood and drain principle. When hot air is required from the fan coil the heater's water pump is activated pumping hot water to the fan coil forcing the air in the delivery and return pipes to the fan coil and the air in the coil itself, back to the air gap cavity in the top of the heater's tank.

When the heater's water pump is switched off, the water in the coil and the delivery and return pipes form the coil floods back into the tank forcing the air in the top of the tank to replace the returning water from the fan coil which is flooding back into the tank. The flood and drain delivery system prevents freezing of water in the fan coil and the delivery and return pipes in circumstances where the unit is in freezing conditions. This flood drain water delivery and return principle can also be applied to traditional heating panels with the same advantages. In this arrangement a circulating pump 97 is provided to circulate

water from the tank through the hydronic fan coil units and then return to the return inlet 46. In this arrangement, the return inlet 46 is located just below the top 61 of the tank so that the return water will flow into the air gap 75. During installation, the water in the tank is heated up to operating temperature, say 100° before the water level indicator fitting 59 is plugged. This ensures that the pressure of the air in the air gap does not increase above atmospheric. The pump 97 does not normally form part of the heater and is provided in the system when required.

Figure 30 diagrammatically shows a modified water heater which is similar to that shown in Figure 29 except that it is provided with a second heat transfer coil 99 which is connected in series with the heat transfer coil 26. Preferably, the second coil 99 is frustoconical and is spaced inwardly from the first coil 26. The provision of the second coil 99 can effectively double the amount of hot water available at the outlet lines 36 and 38.

Figure 30a shows a schematic view of a modified water heater 434. The same reference numerals have been used to denote parts which are the same as or correspond to those of other embodiments.

In this arrangement, a modified burner assembly 67 is utilised. In this arrangement, the gas burner element 120 is located near the top thereof and the pressure from the fan 142 forces combustion products from the element 120 downwardly so that they escape through a flue outlet opening 405 located in the bottom wall 116 of the housing. The flue gases then pass through a U-shaped flue diversion line 404 and into flue pipe 408 and into the flue 79. In this arrangement the flue control assembly 22 is probably unnecessary because of the U-shaped path of the flue lines acting as an air trap which would effectively prevent convection currents flowing when the burner element 120 is not operating. The unit would be efficient because the flue diversion line 404 would be located near the bottom of the tank 4 and transfer heat thereto. Normally the coldest water would be located near the bottom of the tank and therefore this promotes efficient heat transfer.

Figure 30b shows a further modified water heater 434 which is generally the same as that shown in Figure 30a except that the flue outlet line is coupled to the flue 79 so that the flue gases can pass to solar panels (not shown). The flue 79 includes the blocking plate 87 to prevent escape of flue gases through the vents 81.

Figure 31 schematically shows various plumbing connections to heaters of the type shown in Figures 22 to 30b.

Figures 32, 33 and 34 illustrate how some of the novel principles of the invention can be applied to electric water heaters in order to improve the efficiency thereof. These electric heaters utilise the air gap principles and the flood drain heating principles as described above in relation to all electric heaters. They would not require pressure temperature relief valves and therefore avoid losses which are normally incurred with conventional all electric water heaters which do require pressure temperature relief valves.

Figure 32 shows a modified water heater in which a second electric element 101 replaces the gas burner assembly 6. In this arrangement the second temperature sensing element 100 controls the operation of the second element 101. Again, the heater is provided with a pump 97 for circulating water from the tank to hydronic fan coil heating units (not shown). Typically the capacities of the heating elements are as follows about 3600 watts for each of the elements 80 and 99.

Figure 33 is similar to Figure 32 except that increased capacity is provided by the second heat transfer coil 99. In addition, there may be a number of additional heating elements connected in parallel with the heating element 101, such as the heating elements 101A, 101B and 101C as diagrammatically illustrated in Figure 34 so as to provide the necessary input power.

Figures 35 and 36 show a preferred form of the solar pre-heating tank 174 which can be utilised in the systems illustrated in Figure 9A and related systems. As many of the mechanical details of the solar pre-heating tank 174 are similar to the hot water tank 4,

manufacturing can be substantially simplified if the same basic unit is used for both tanks 4 and 174. This results in savings in tooling costs and inventory costs.

The tank 174 is preferably cylindrical and includes sidewalls 175, top and bottom walls 181 and 183. The tank is located within a cylindrical housing 185, an insulating layer 187 being located between the tank and the housing. The coil 190 may be of the same or similar construction as the coil 26 and it is retained in position by upper and lower coil stabilising arms 189 and 195. The tank 174 includes a pressure relief valve 209 which operates if the internal pressure of the tank reaches 3 atmospheres. The tank also includes a level indicator fitting 210 which functions analogously to the fitting 59 of the tank 4.

On installation of the tank 174, water is introduced through the outlet 176 and water is filled to the level of the level indicator fitting 210. This creates an air gap 211 at atmospheric pressure. A sacrificial element 212 which may be similar to the element 63 is located in the air gap 211 to react with oxygen. The outlet 176 is connected to the pump 180 and the level indicator fitting 210 is then plugged. When the pump operates, it draws water from the tank 174 and circulates it to the solar panel 172 and returns via the fitting 177 into the air gap 211, as diagrammatically illustrated in Figure 36. When the pump 180 operates, it causes air in the panel 172, supply line 178 and return line 182 to be forced into the top of the tank to thereby increase the effective size of the air gap 211, as indicated in Figure 36. For this reason, the coil 190 is located at a somewhat lower level in the tank 174 to ensure that the uppermost convolution of the coil 190 is not in the air gap 211. The pump 180 does not normally form part of the unit and is included in the system when required.

When the pump 180 does not operate, water runs back to the tank 174 mainly via the line 178 to thereby avoid potential problems of water being retained in the panel 172, as diagrammatically shown in Figure 36.

Figures 37 and 38 diagrammatically illustrate a combined water heater and solar storage tank, constructed as a combined unit 213. The unit 213 can be regarded as the

water heater as illustrated in Figures 22 to 30 mounted on top of the solar pre-heating tank 174 as illustrated in Figures 35 and 36. There is, however, no insulation between the two tanks and the bottom 39 of the tank 4 can be welded to the top 181 of the tank 174. The housing 40 is made long enough so that it encloses both tanks. Alternatively, the tanks 4 and 174 could be formed by having a central partition in a single cylindrical tank structure.

Figure 38 shows the combined unit 213 in more detail. It will be seen that the tank 174 includes reinforcing rods 214 which are connected to the top 181 and bottom 183 of the tank 174. The rods 214 serve to prevent buckling of the ends of the tank 174. In the preferred arrangement, there are four of the rods 214 and these are aligned with corresponding rods 93 in the tank 2. This further assists in support of the tanks.

It is preferred to have the tank 4 above the tank 174. In circumstances where the temperature of the water within the tank 174 is lower than the temperature of the water in the tank 4, heat will not be transferred from the upper tank 4 to the lower tank 174 through convection. On the other hand, when the temperature of the water within the lower tank 174 is higher than the temperature of water in the upper tank 4, heat will be transferred from the lower tank to the upper tank which provides more heat into the upper tank for hot water and/or heating purposes. It will be appreciated that the combined unit 213 is a very compact and efficient way of providing a combined domestic hot water service which has a pre-heating tank for providing pre-heating of the water passing through the hot water service. It is compact and easy to manufacture because many of the components of the two tanks are the same and they can be located within a single housing. Heat losses are minimised because of the proximity of the two tanks and no losses would be sustained in lines which are used to interconnect the two tanks if they were in separate housings.

Figure 39 illustrates a modified combined unit 215 which is similar to the arrangement shown in Figure 38 except that the tanks 4 and 174 are constructed as a single tank 217 which includes a barrier plate 216 to define the hot water tank 4 and the solar pre-heating tank 174. The plate 216 may include openings or perforations therein to allow limited convectional flow of water between the tanks. Normally the water within the tanks

will be stratified according to temperature. Accordingly, when the temperature of the water within the lower tank 174 is lower than the temperature of the water within the upper tank 4, there will be no convection flow through or past the plate 216. When, however, the temperature is higher in the lower plate, there will be convection flow and this provides useable heat to the upper tank.

Figures 40 to 43 illustrate an alternative construction for the solar absorber panel, similar to that described in relation to Figures 12A and 12B above. The same reference numerals have accordingly been used to denote parts which are the same as or correspond to those in the earlier embodiment.

Figure 40 diagrammatically illustrates a preferred form of solar absorber panel 350 and Figure 41 shows the components which make up the panel 350 in schematic exploded view.

Figure 41 shows the components which make up the panel 350 in a schematic exploded view. The components include the glass sheet 247 beneath which are located upper, intermediate and lower stainless steel sheets 352, 354 and 356. The upper sheet 352 is pressed so as to have laterally extending indentations or grooves 358 thereon. Normally these are about 3mm deep. The edges of the upper sheet 352 are formed with edge flanges 360 to facilitate joining of the upper sheet 352 to the intermediate sheet 354 by means of welding or the like. When the sheets 352 and 354 are joined, a water cavity 362 is defined therebetween, as shown in more detail in Figure 42. The edges of the intermediate sheet 354 are formed with downturned flanges 364 whereas the edges of the lower sheet 356 are formed with upwardly facing channels 366. The underside of the intermediate sheet 354 has a plurality of U-shaped channel sections 368 connected thereto by spot welding or the like. The lower sheet 356 is joined to the intermediate sheet 354 by spot welding or the like. The flanges 364 and the channels 366 combine to form an inlet manifold 369 and outlet manifold 370. The manifolds 369 and 370 extend along respective sides of the panel and the hot flue combustion products from the water heater 2 are introduced into the manifold 369 and then flow through a gas cavity 372 defined between the intermediate and

lower sheets 354 and 356, which remain spaced apart by the channel sections 368. The flue gases transfer heat to water within the water cavity 362 by conduction and the cooled flue gases are expelled through the manifold 370.

Insulation 374 is provided so as to be located beneath the lower sheet 356. The insulation 374 is provided with rebates 376 along its lateral edges so as to accommodate the manifolds 369 and 370 in the completed assembly as shown in more detail in Figure 42.

The panel includes a base 378 which can be formed from sheet metal such as galvanised iron. Its edges are formed upwardly so as to define sides 380 of the panel. The sides are shaped so as to define inwardly facing grooves 382 for receipt of the glass sheet 247.

The top surface of the upper sheet 352 is preferably treated so that it is absorbent. This may be done by heat treatment of stainless steel to make it selectively absorbent of solar energy, in a known manner. Alternatively, absorbent coatings may be applied thereto.

This arrangement provides an inexpensive solar panel which has a water cavity 362 for heating water circulated therein and a gas cavity 372 for transferring heat from the flue gases to the water circulating in the water cavity 362.

Figures 45A, B, C and D diagrammatically show how the panel 350 fills with water in use.

Figure 45A shows the panel when not in use. In this condition the water in the water cavity 362 has been drained back to the solar pre-heating tank 174 through the outlet 198. This prevents the possibility of damage caused by freezing of water within the water cavity.

When the pump 180 operates, water from the tank 174 flows into the inlet 196 and begins to flood the water cavity 362. As described previously, the sensors 184 and 186 control the pump 180 and in the illustrated arrangement the sensor 184 can be connected to the upper surface of the upper plate 352. As the pump 180 continues to operate, water gradually fills the cavity 362 as illustrated in Figure 45C. Air within the water cavity 362 is expelled and returned to the solar tank 174. When the cavity 362 is completely filled, as shown in Figure 5, water will be circulated therethrough and be heated by absorption of solar energy. The indentations or grooves 358 define generally laterally extending flow paths for the water within the cavity 362.

Figure 46 diagrammatically illustrates a modified combined unit 400 which is similar to the combined unit 213 shown in Figures 37 and 38 except that it includes a heat exchanger 402 for extraction of heat from flue gases from the burner 6. More particularly, it will be seen that the heat exchanger 402 is located near the bottom of the tank 174. It receives flue gases from the burner assembly 6 via a flue diversion line 404 which is coupled to the flue pipe 8 from the burner assembly 6. It is preferred that the heat exchanger 402 be constructed in an analogous way to the burner assembly 6. This again would simplify tooling costs and reduce inventory costs. Basically, the heat exchanger 402 may utilise the same housing 110 of the assembly 6 except that a flue gas distribution manifold 406 is substituted for the gas burner element 120. The distribution manifold 406 may take the form of a hollow cylindrical body formed with holes 407 therein to permit flue gases to enter the interior of the heat exchanger. Water within the tank 174 will pass through the heat transfer tubes 124, as in the case of the burner assembly 6, once flue products are introduced into the heat exchanger 402. The heat exchanger 402 includes a drainage duct 410 for draining condensate from within the heat exchanger. The duct 410 includes a water trap 412, the height of which is at about the same level as the bottom wall 116 of the heat exchanger so as to prevent escape of flue gases from within the heat exchanger through the duct 410.

The pre-heating tank 174 can also be heated by solar panels coupled via the lines 178 and 182, as in the embodiment of Figure 38. Flue products from the heat exchanger

402 pass into a flue pipe 408 which passes through the sidewall 175 of the tank and then within the housing 40 to the flue 79. Thus, the combined unit 400 functions analogously to the combined unit 213 except that there is additional heat extraction into the pre-heating tank 174 from the flue gases of the gas burner. This of course increases overall efficiency.

The heat exchanger 402 may also include an auxiliary input 414 for input of hot gases from an alternative source, such as the exhaust of an internal combustion engine as in the arrangement of Figure 17. In this arrangement, the exhaust products flowing in the inlet duct portion 252 after the venturi 279 could be coupled to the auxiliary input 414 so that heat can be extracted therefrom into the water within the tank 174. The exhaust gases would ultimately be expelled through the flue 79.

Figure 47 illustrates a further modified combined unit 420 which is similar in construction and function to the combined unit 400 shown in Figure 46 except that a heat exchange coil 422 is provided in the tank 174 beneath the heat exchanger 402. The heat exchanger 402 may comprise a helical coil 424 of copper tube located within a housing 426. The helical coil receives cold water from the mains inlet line 32 and pre-heats it prior to being admitted to the heat transfer coil 190 located at the top of the tank 174. The housing 426 receives flue products from the interior of the heat exchanger 402 via inlet line 428. The housing 426 is coupled to the flue pipe 408 via an outlet line 430, as shown. In this arrangement any heat remaining in the flue and/or exhaust products supplied to the heat exchanger 402 will be passed to the water flowing within the coil 422. Even though the flue gases and/or exhaust gases may be considerably cooled within the heat exchanger 402, they will almost certainly be above the temperature of the ambient water flowing in the mains inlet line 32. Accordingly, useful heat can be extracted from these gases and utilised in the pre-heating tank 174.

Figure 48 schematically illustrates a further modified combined unit 444. In this embodiment the same reference numerals have been used to denote parts which are the same as or correspond to those of the previous embodiment. In this arrangement, a modified burner assembly 67 of the type similar to that shown in Figures 30a and 30b is

utilised and the flue gases pass through the flue diversion line 404 into a flue gas passage cavity 432 located above the pre-heater tank 433. In this arrangement the diameter of the pre-heater tank 433 is somewhat smaller than the diameter of the tank 4 so as to create a flue gas cavity 436 which surrounds the tank 433 and enables heat transfer of heat from the exhaust gases through the walls of the tank 433 to the water stored therein. In this arrangement the top 441 of the tank 433 is angled so that any condensate will run into the cavity 436 and be collected at the bottom of the housing. It will be seen that the bottom 445 of the housing is also inclined so as to direct condensate to the water trap 212. The cavity 436 is connected via opening 438 into the flue pipe 408 for passage upwardly to the flue 79. In this arrangement the U-shaped path of travel of the combustion products acts as an air trap and therefore the flue control assembly 22 is not required.

Figure 49 shows a further modified combined unit 431 which is similar to that shown in Figure 48. The main difference between the embodiment of Figure 49 and that shown in Figure 48 is the provision of an additional heat exchanger 402 located within the pre-heater tank 433 for extra heat extraction from the flue gases. In this arrangement, the cavity 436 communicates with a lower flue gas cavity 437 located beneath the tank 433. The flue diversion line 404 extends from the cavity 437 into the flue gas distribution manifold 406 of the heat exchanger 402. The flue gases pass through the heat transfer tubes 124 and then into the flue pipe 408. In this arrangement the bottom 442 of the heat exchanger 402 is inclined so that condensate from within the heat exchanger 402 will flow through the drainage duct 410 and into a water trap 446. Again the flow path of the flue gases is such that convection currents will be avoided when the gas burner element 120 is not operating and therefore the flue control assembly 22 is not required. The combined unit 49 extracts significant amounts of heat from the flue gases before expulsion through the flue 79 and hence high efficiency is obtained.

Many modifications will be apparent to those skilled in the art without departing from the spirit and scope of the invention.

DATED this 29th day of April, 2003
OLLIN SUSTAINABLE TECHNOLOGIES PTY. LTD.
By its Patent Attorneys
DAVIES COLLISON CAVE

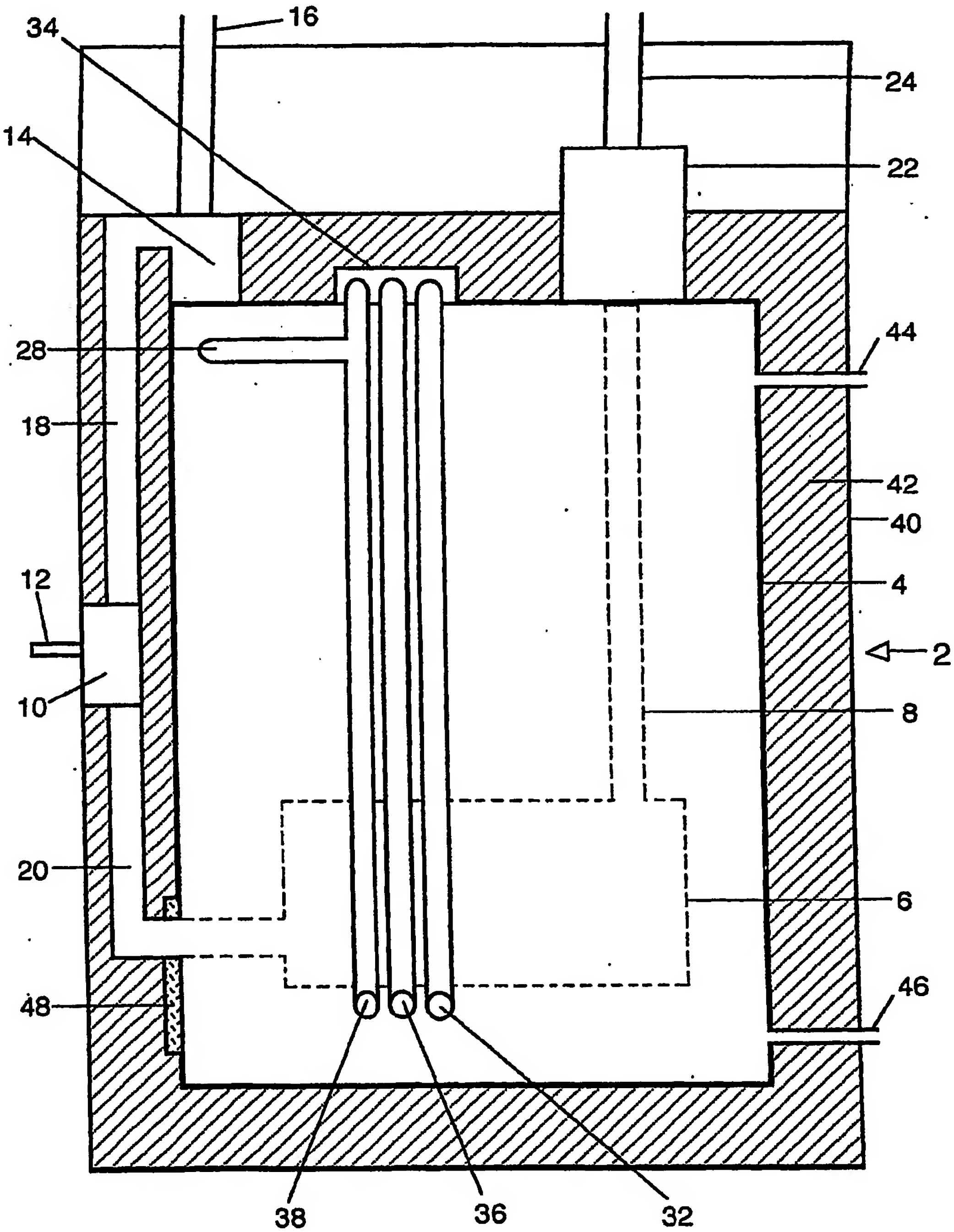

FIG 1.

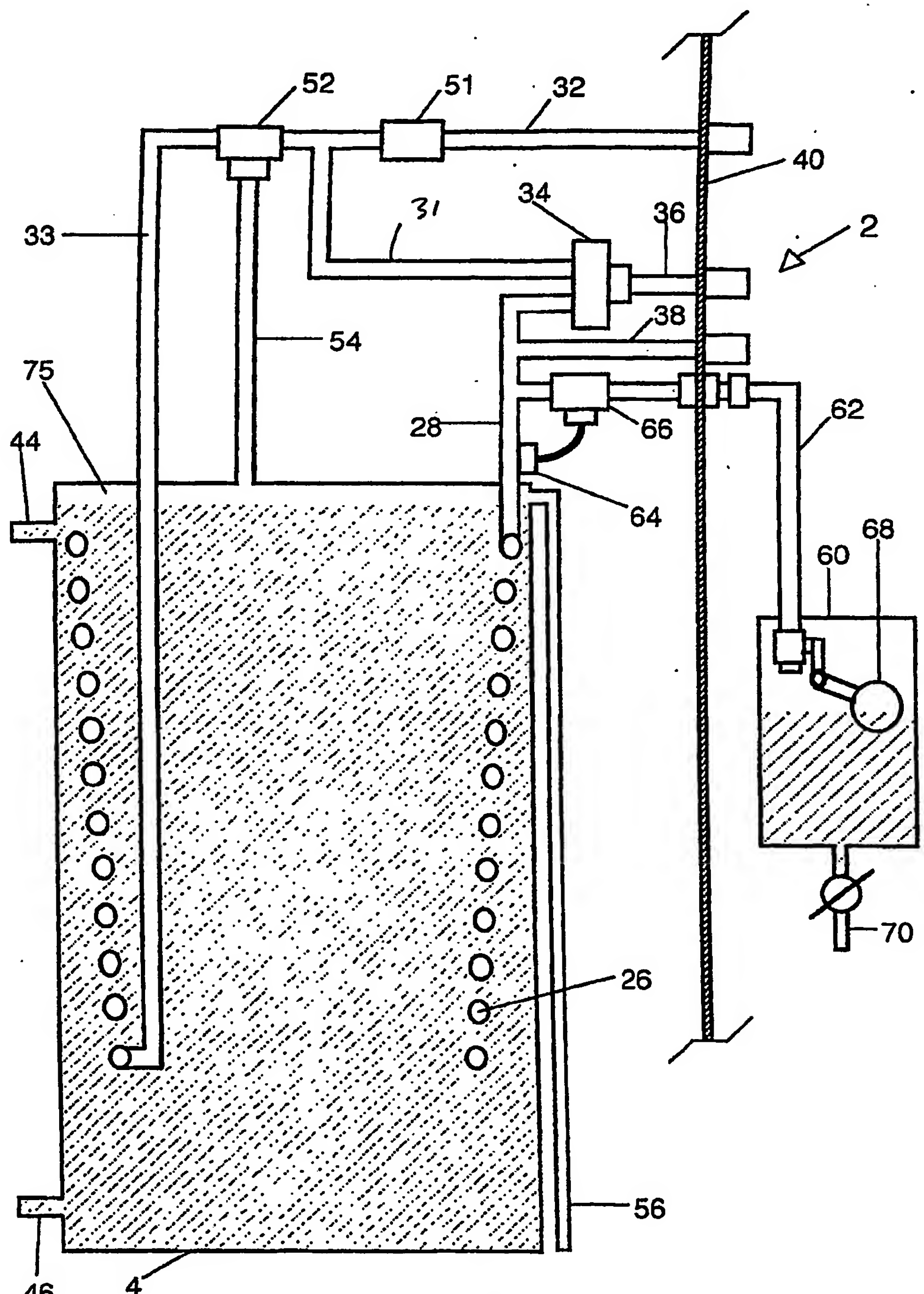

FIG 2 A.

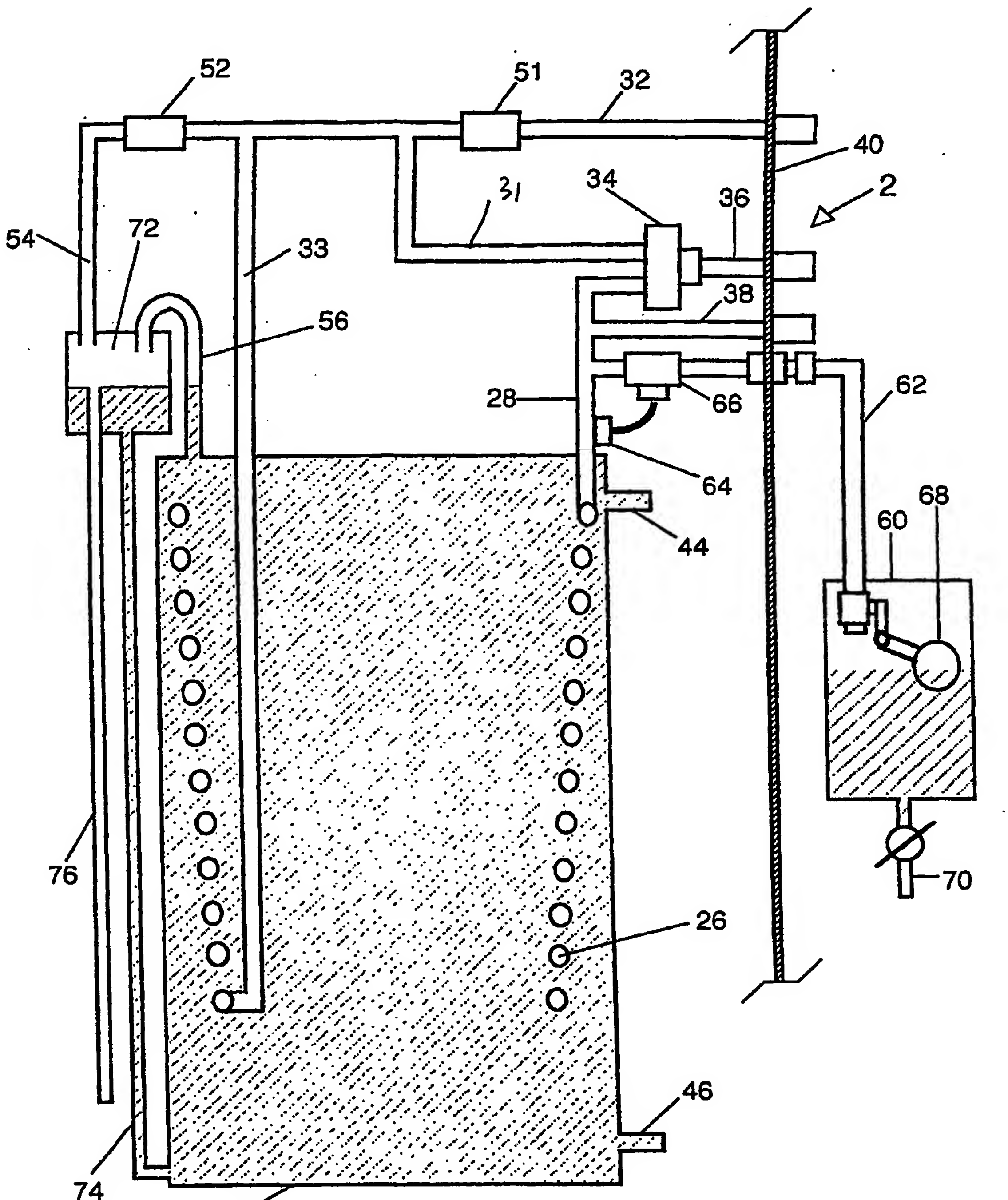
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FIG 2 B.

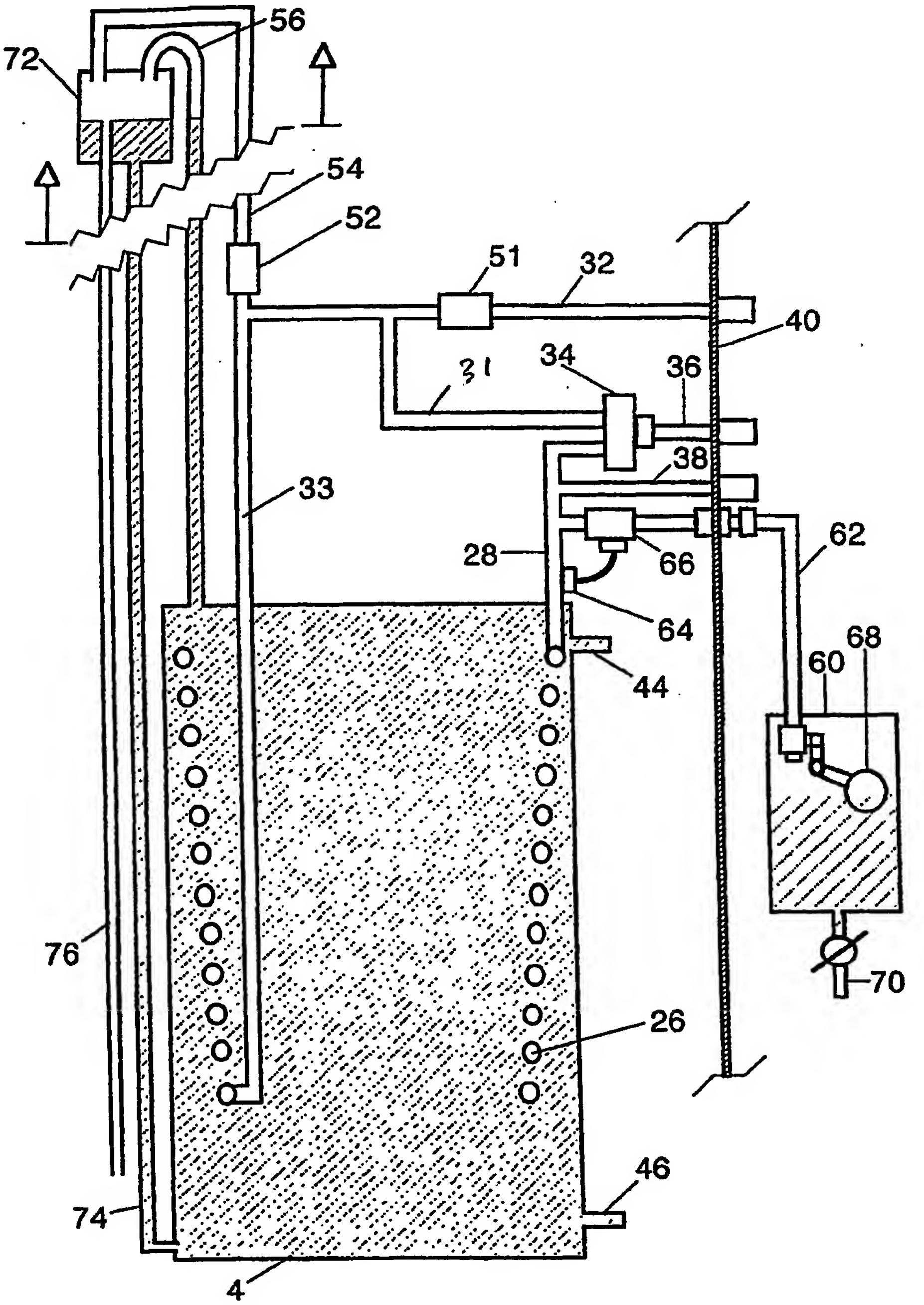

FIG 3.

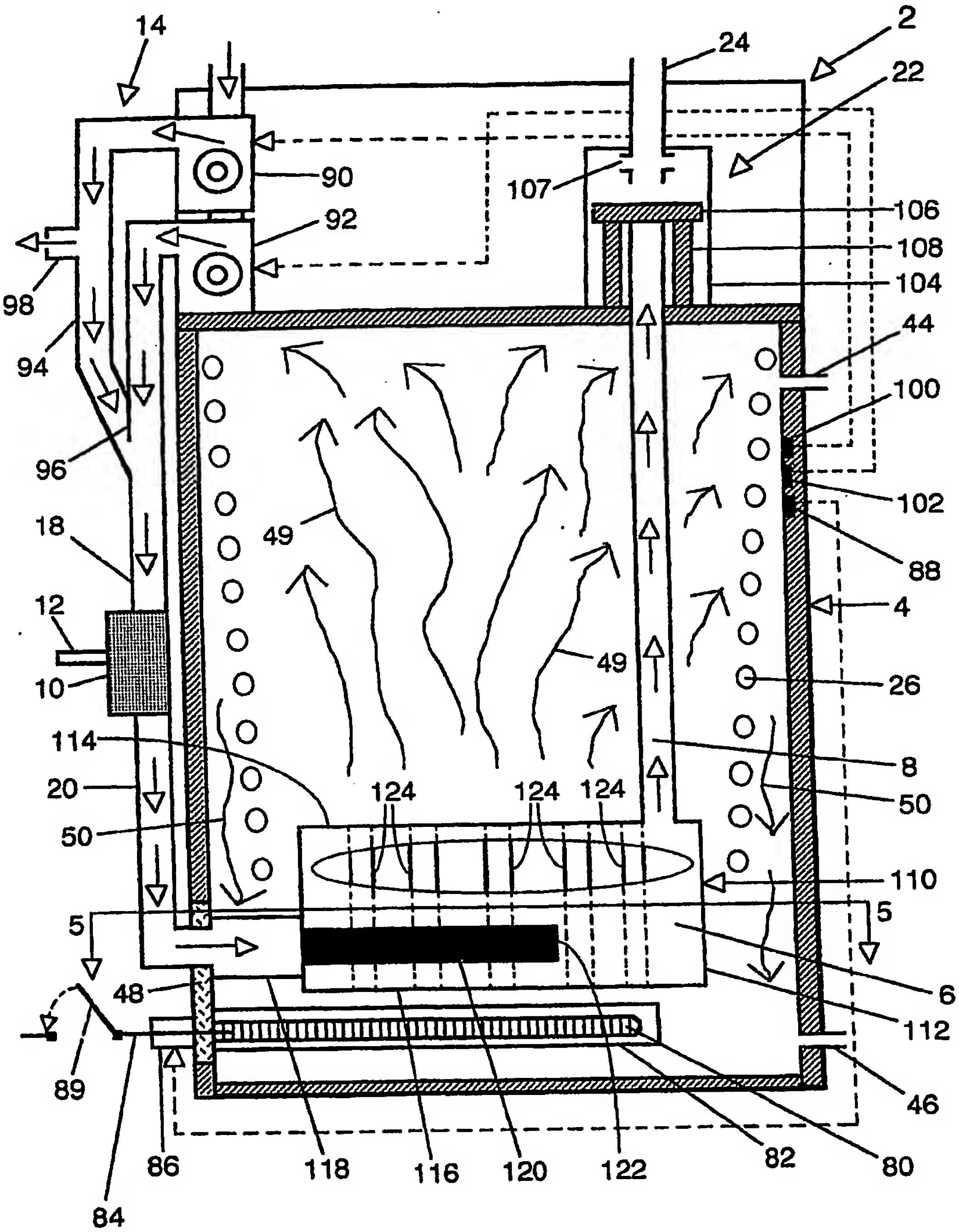
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FIG 4 A.

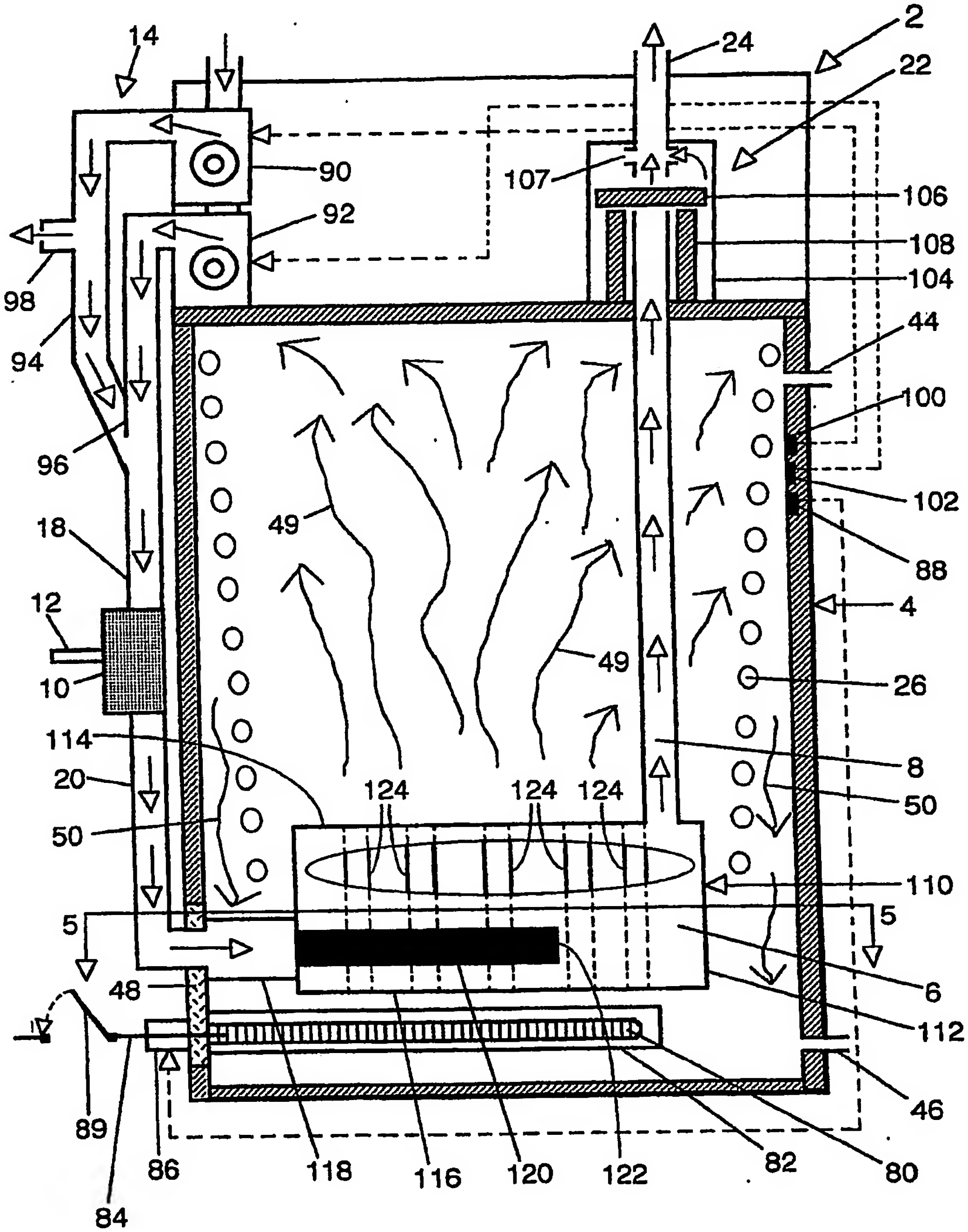

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FIG 4 B.

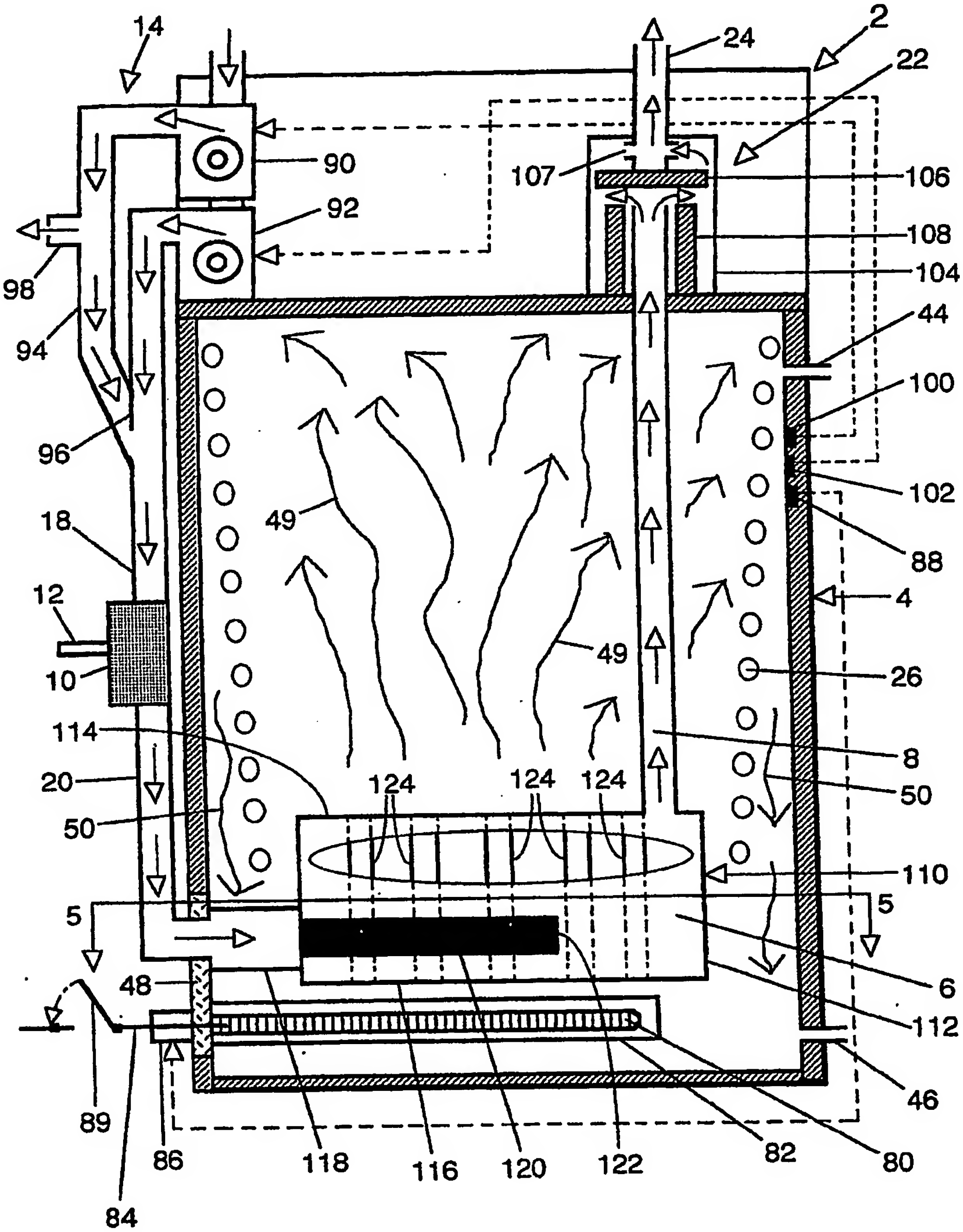
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FIG 4 C.

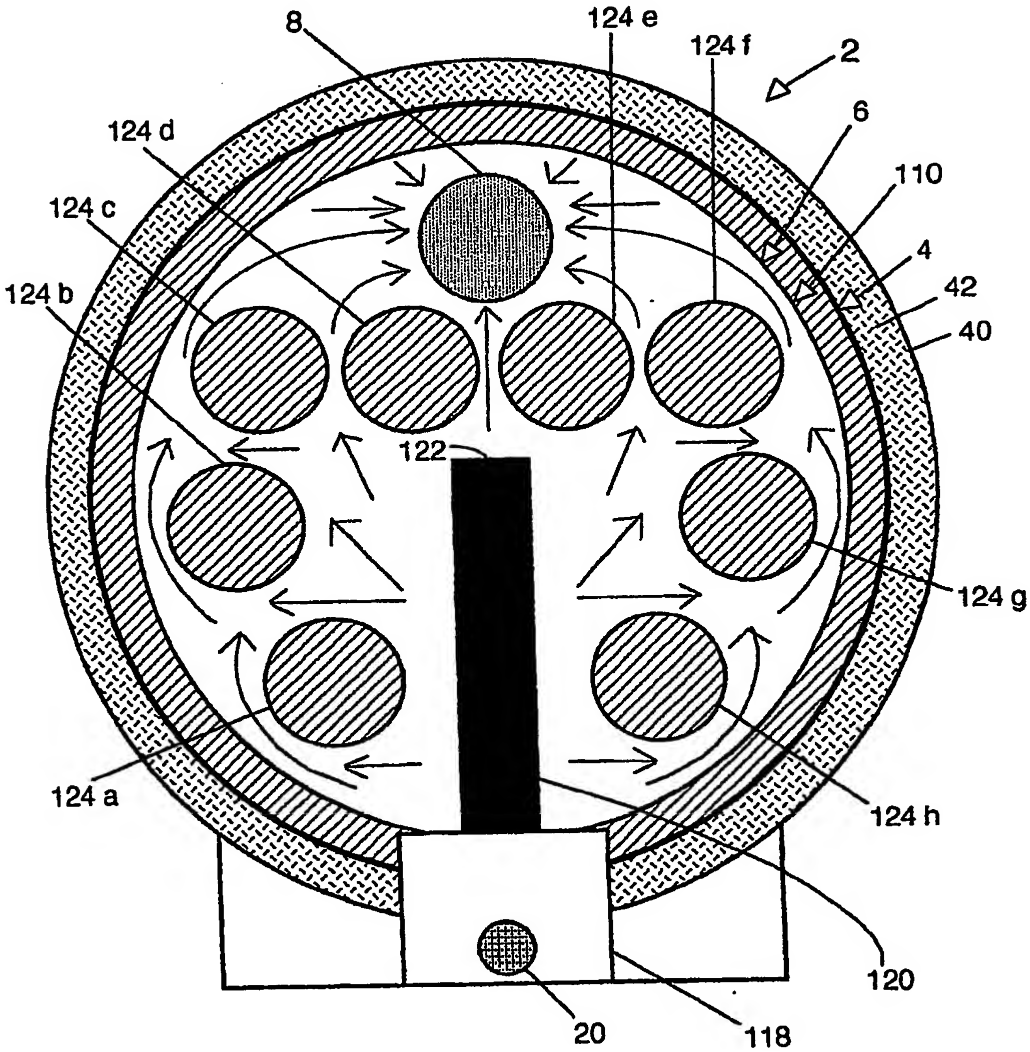

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FIG 5.

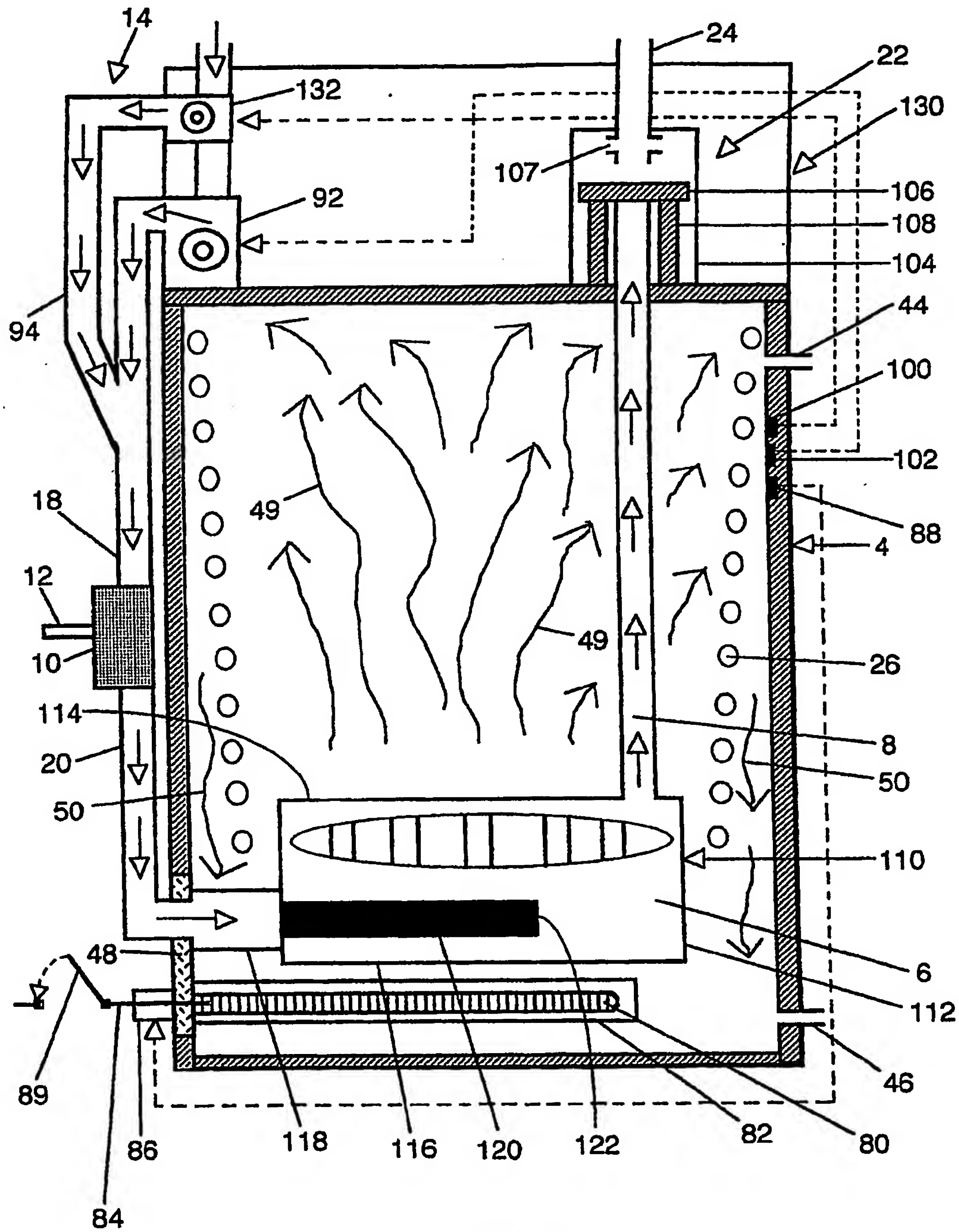

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FIG 6.

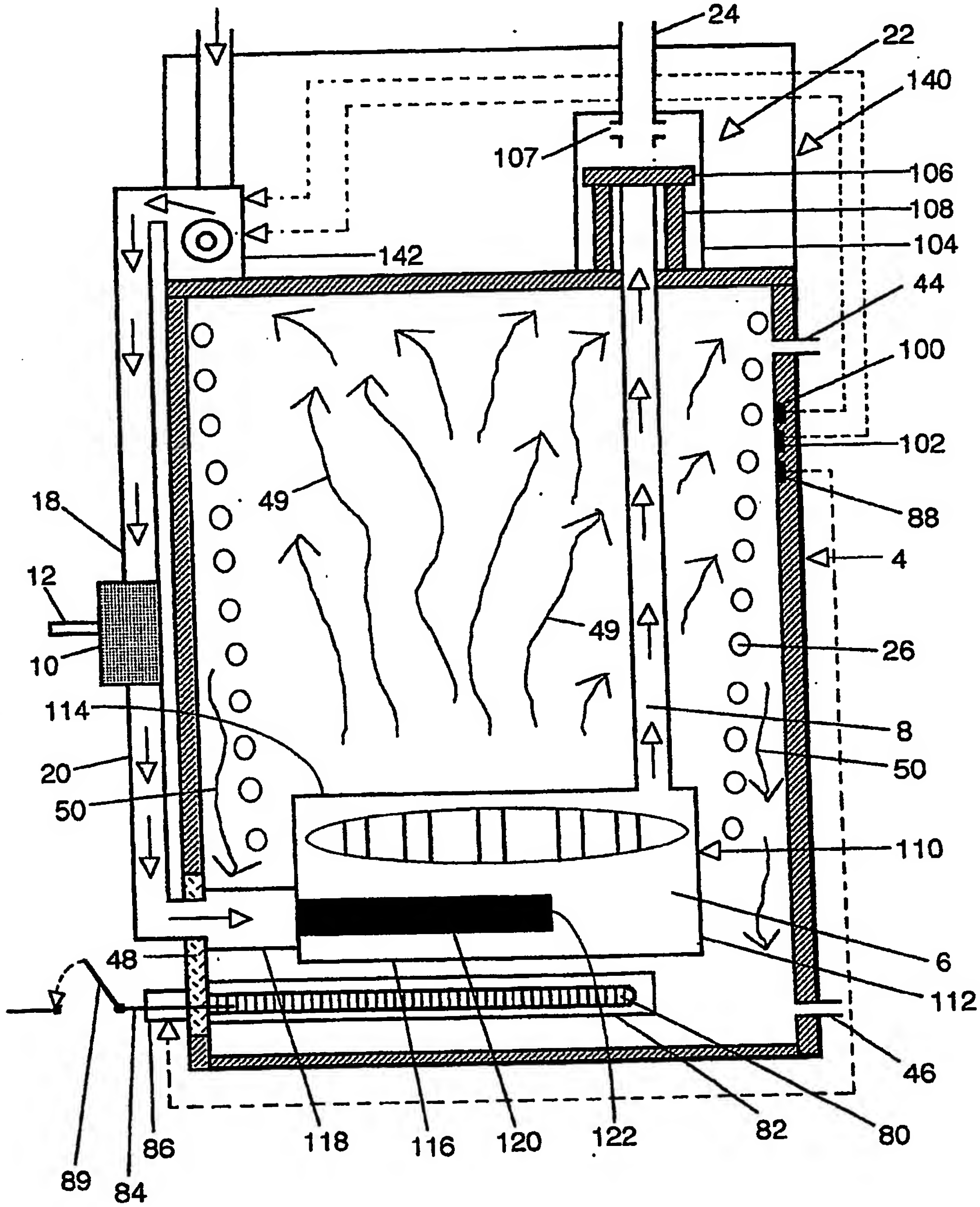

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FIG 7 A.

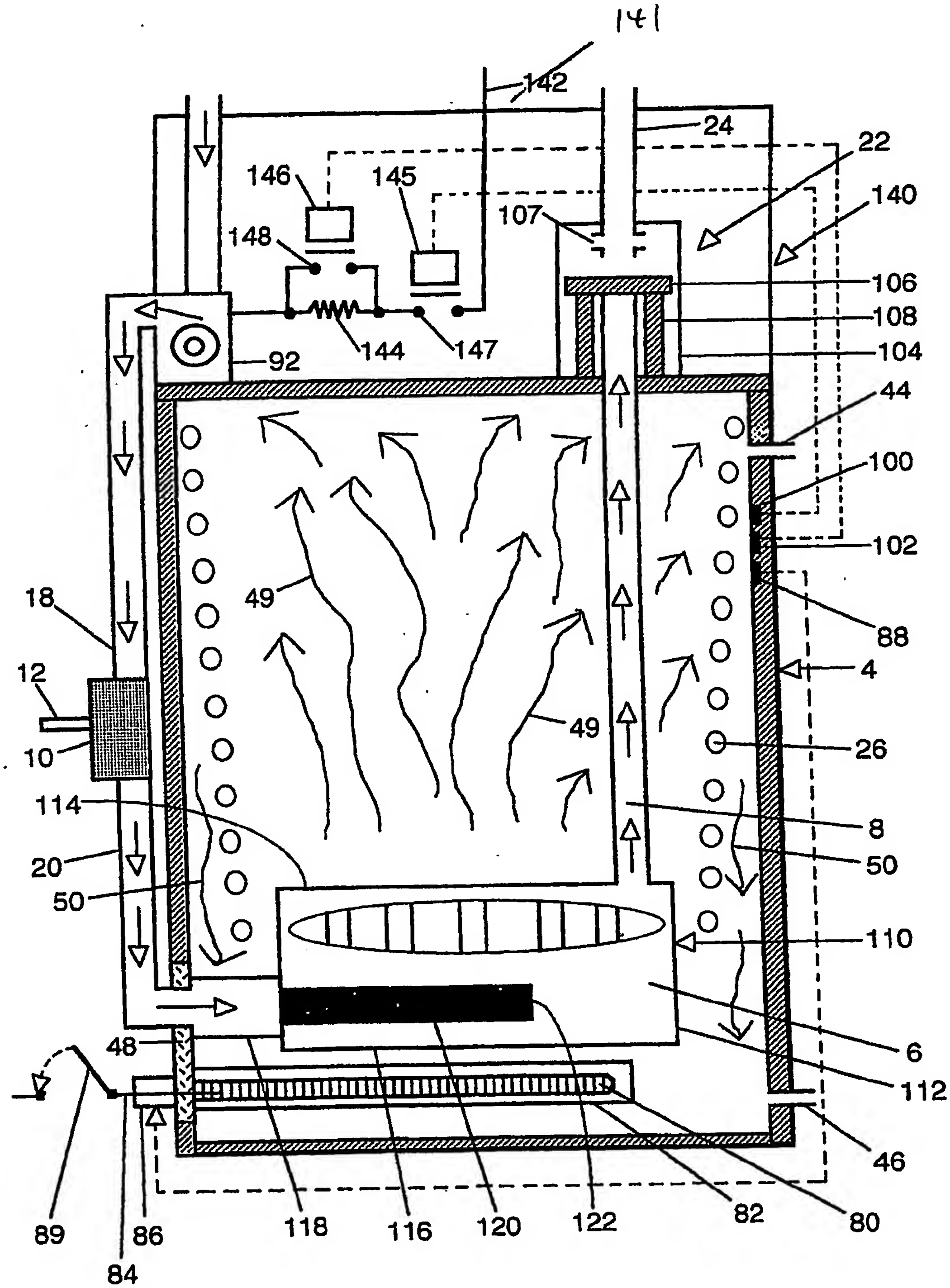
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FIG 7 B.

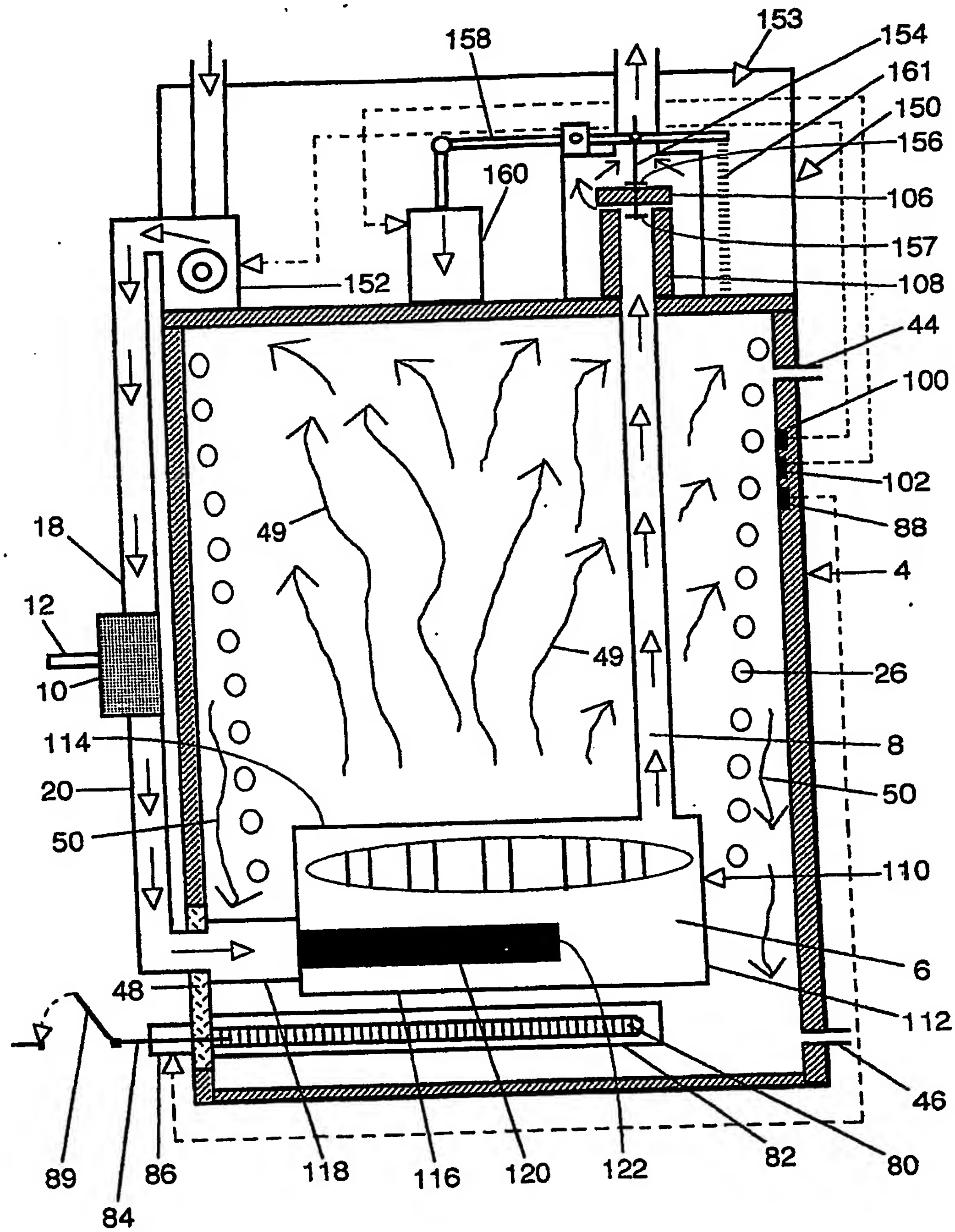
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FIG 8.

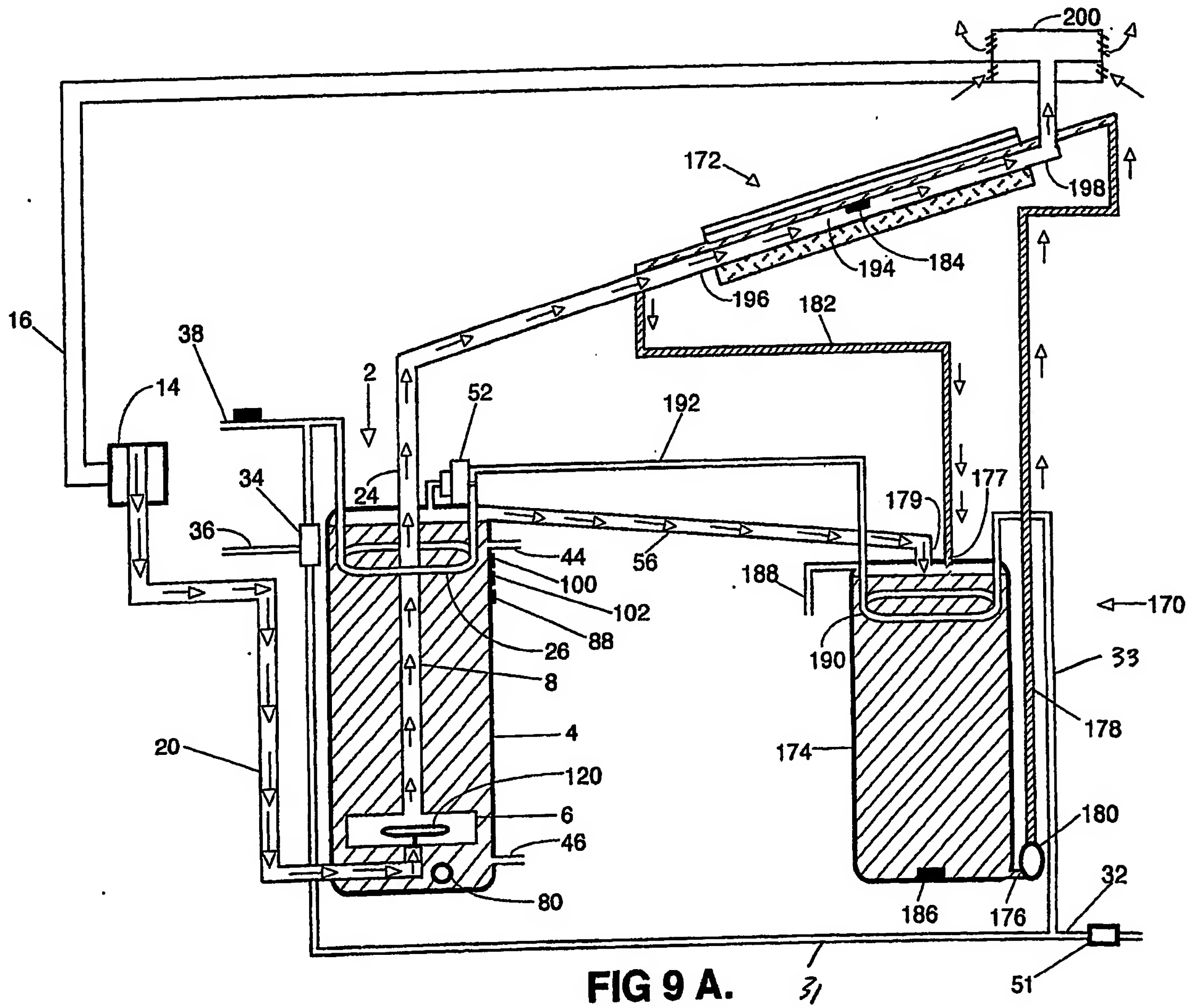
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FIG 9 A.

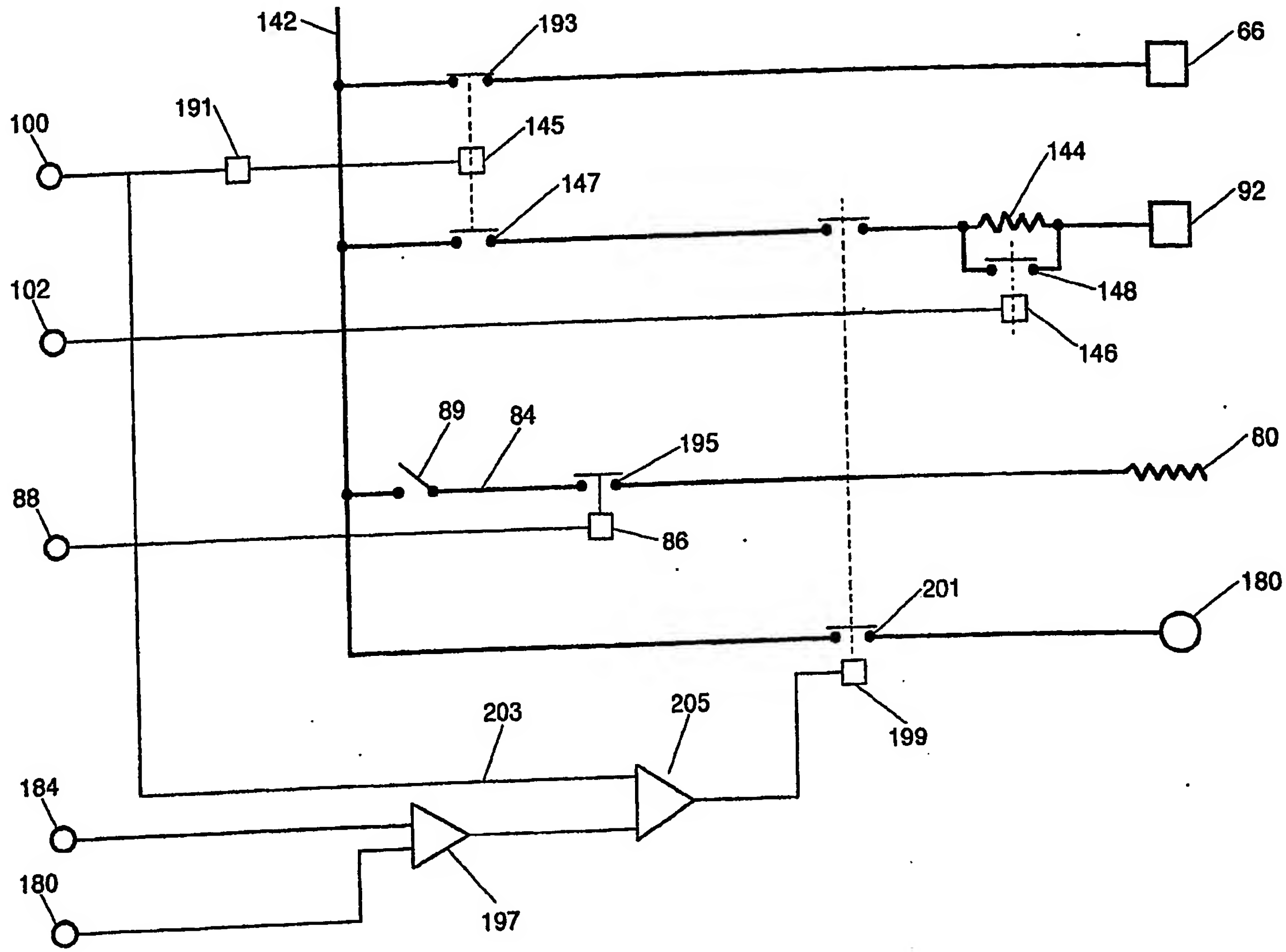
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FIG 9 B.

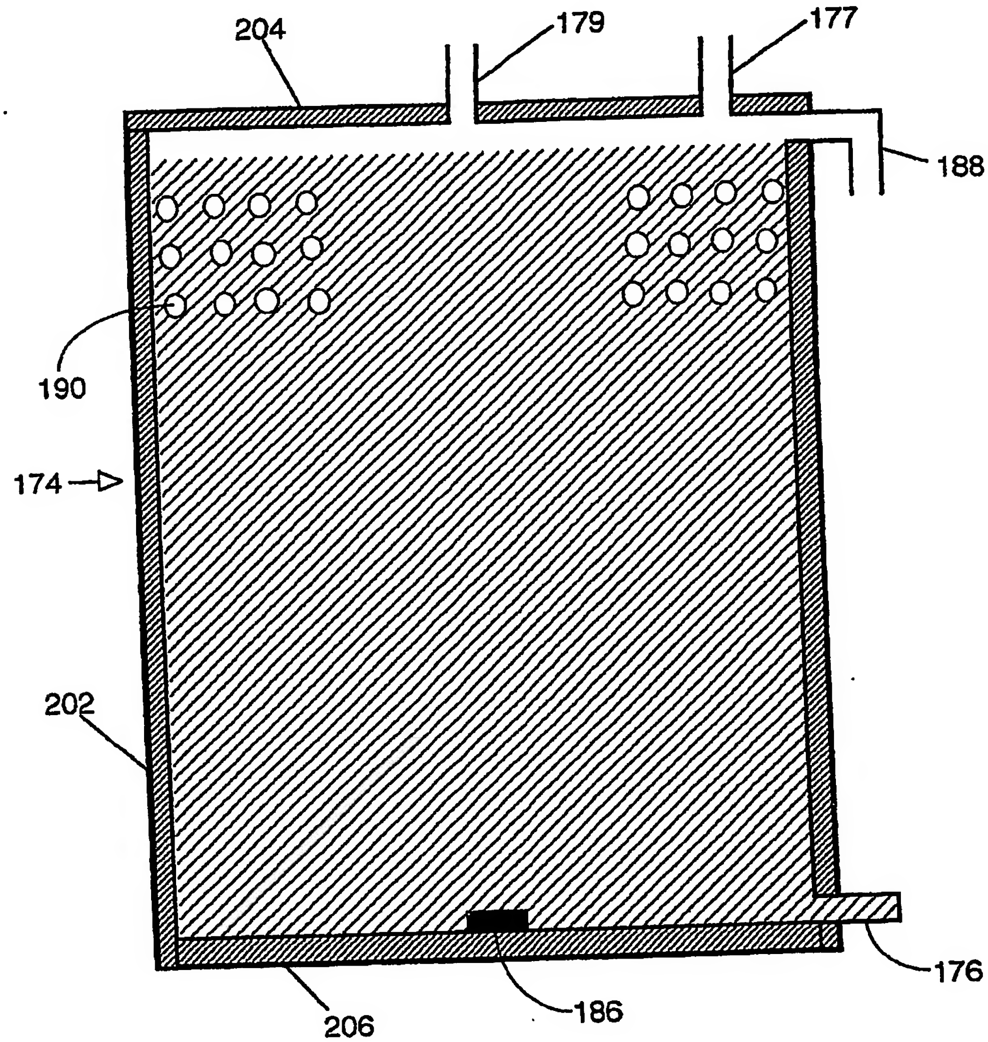

FIG 10.

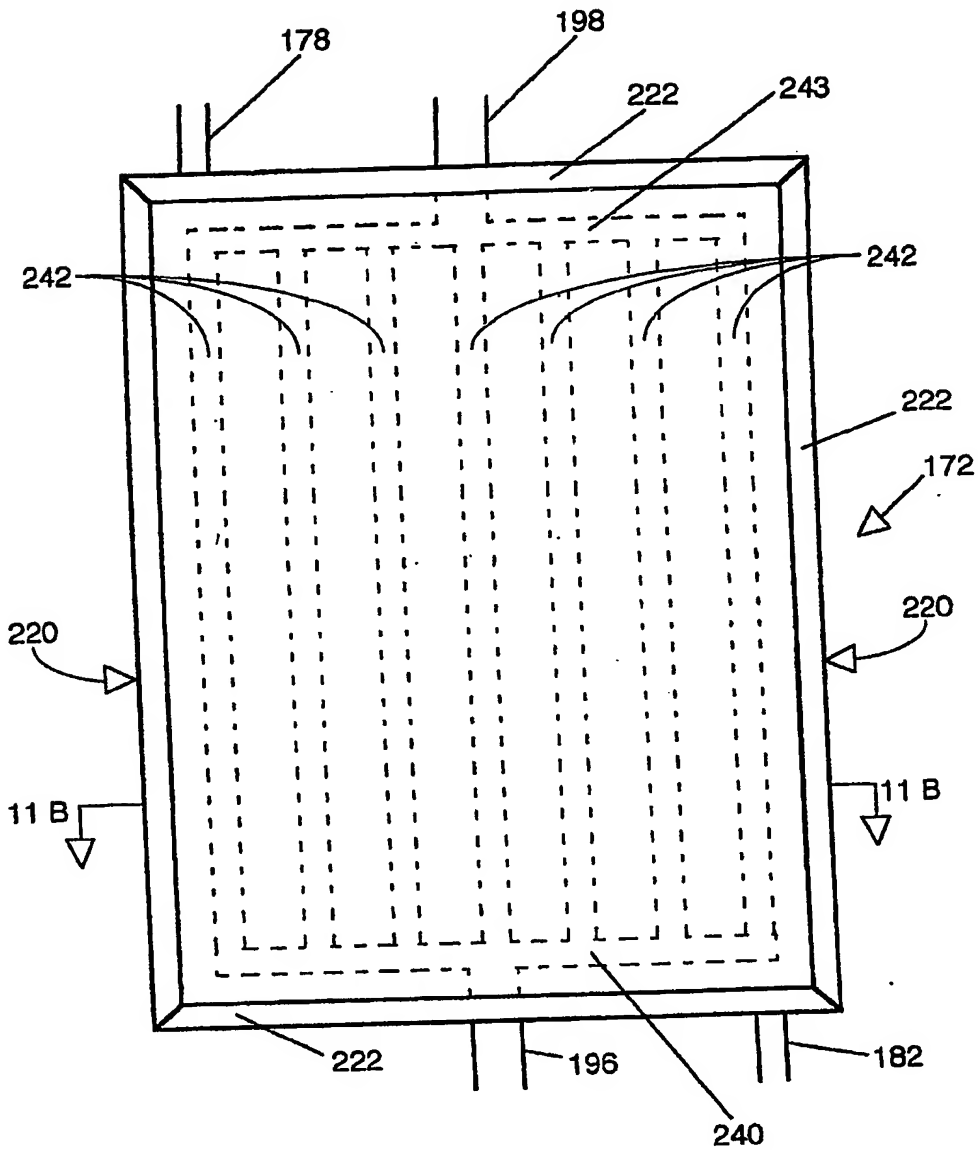

FIG 11 A.

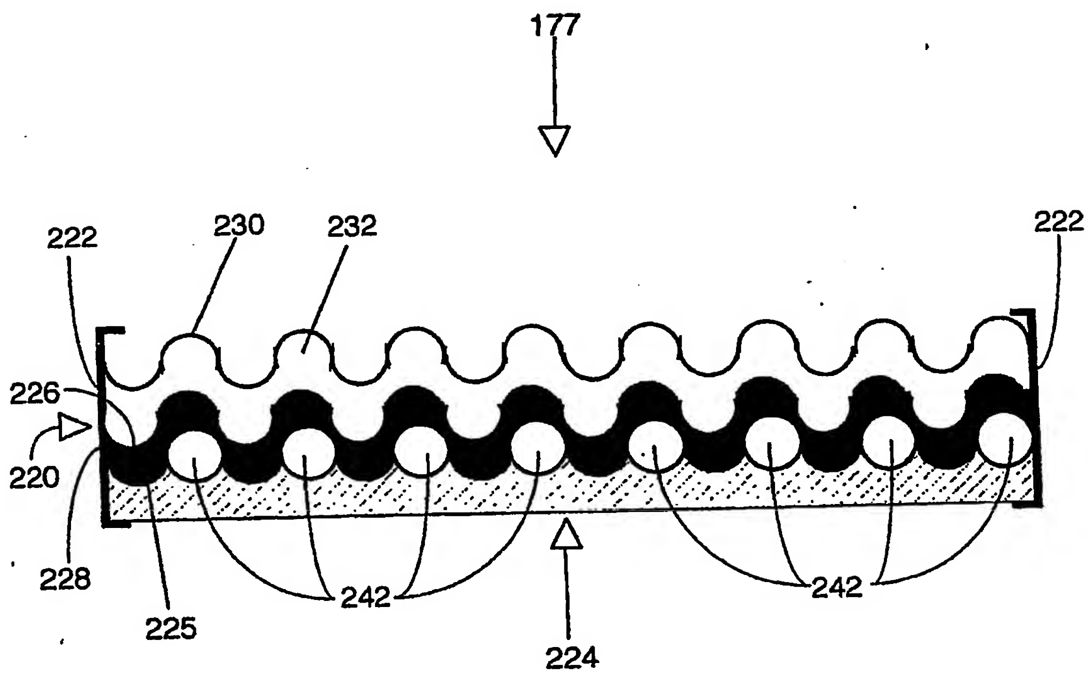

FIG 11 B.

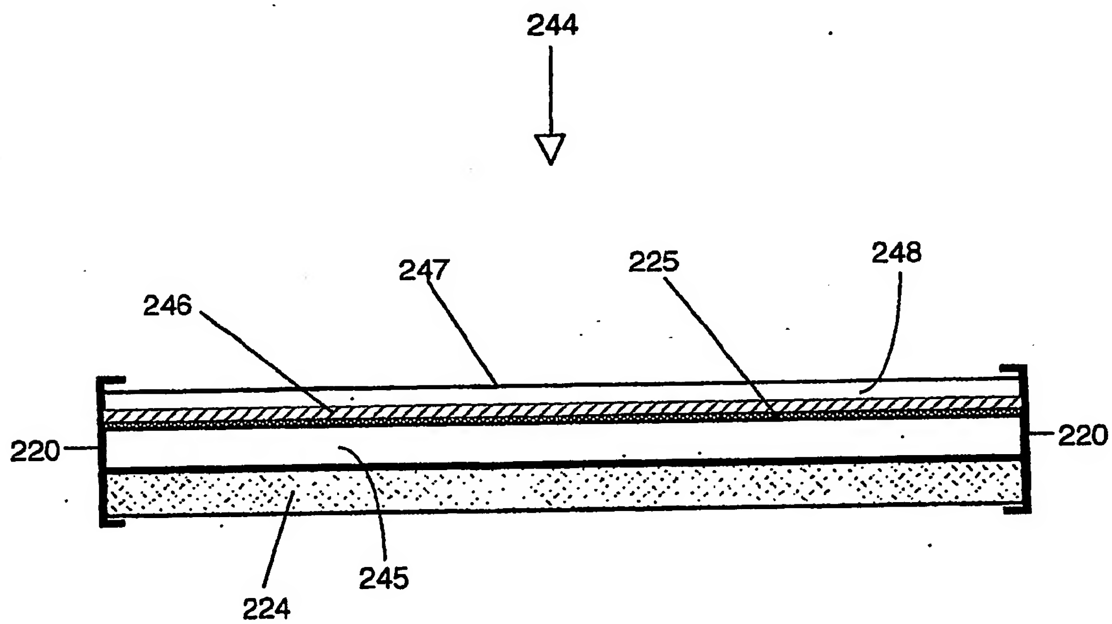

FIG 12 A.

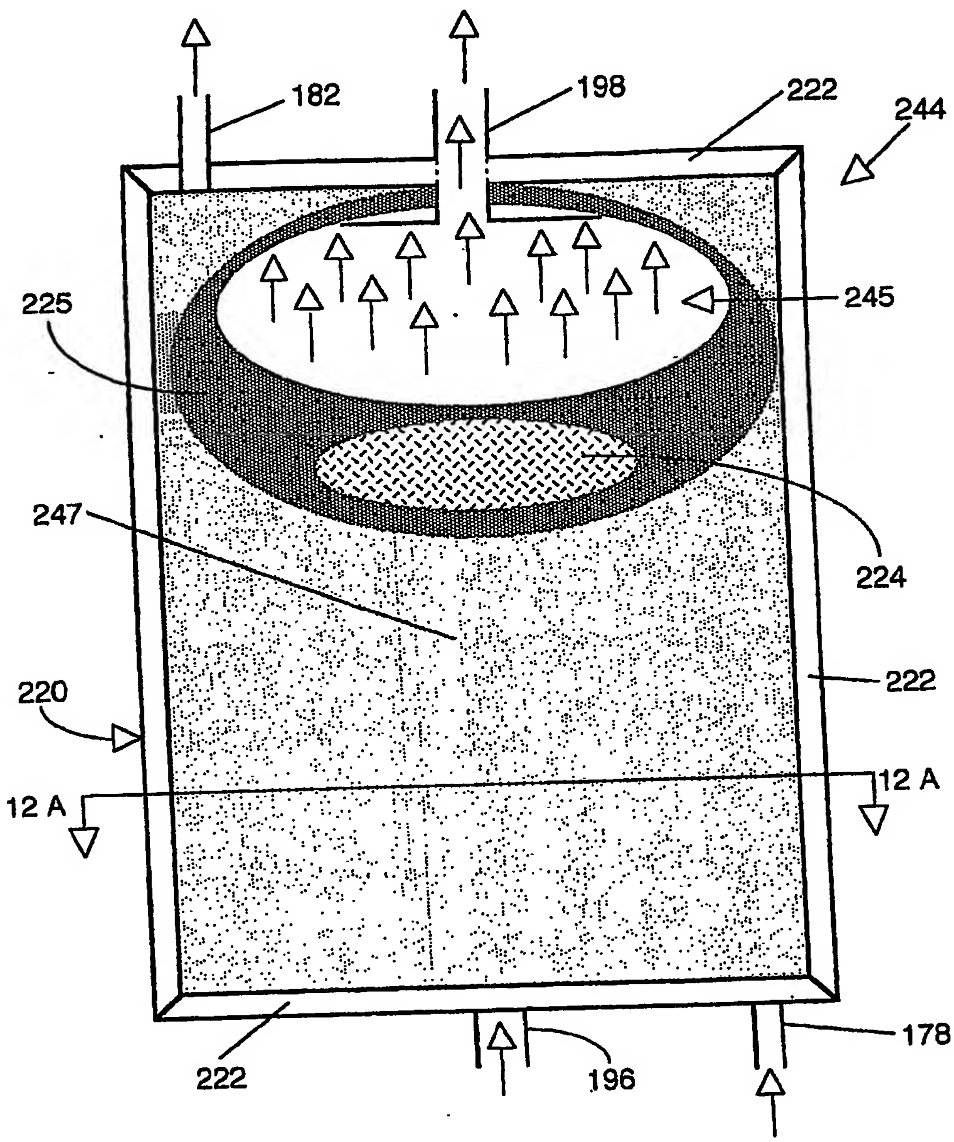

FIG 12 B.

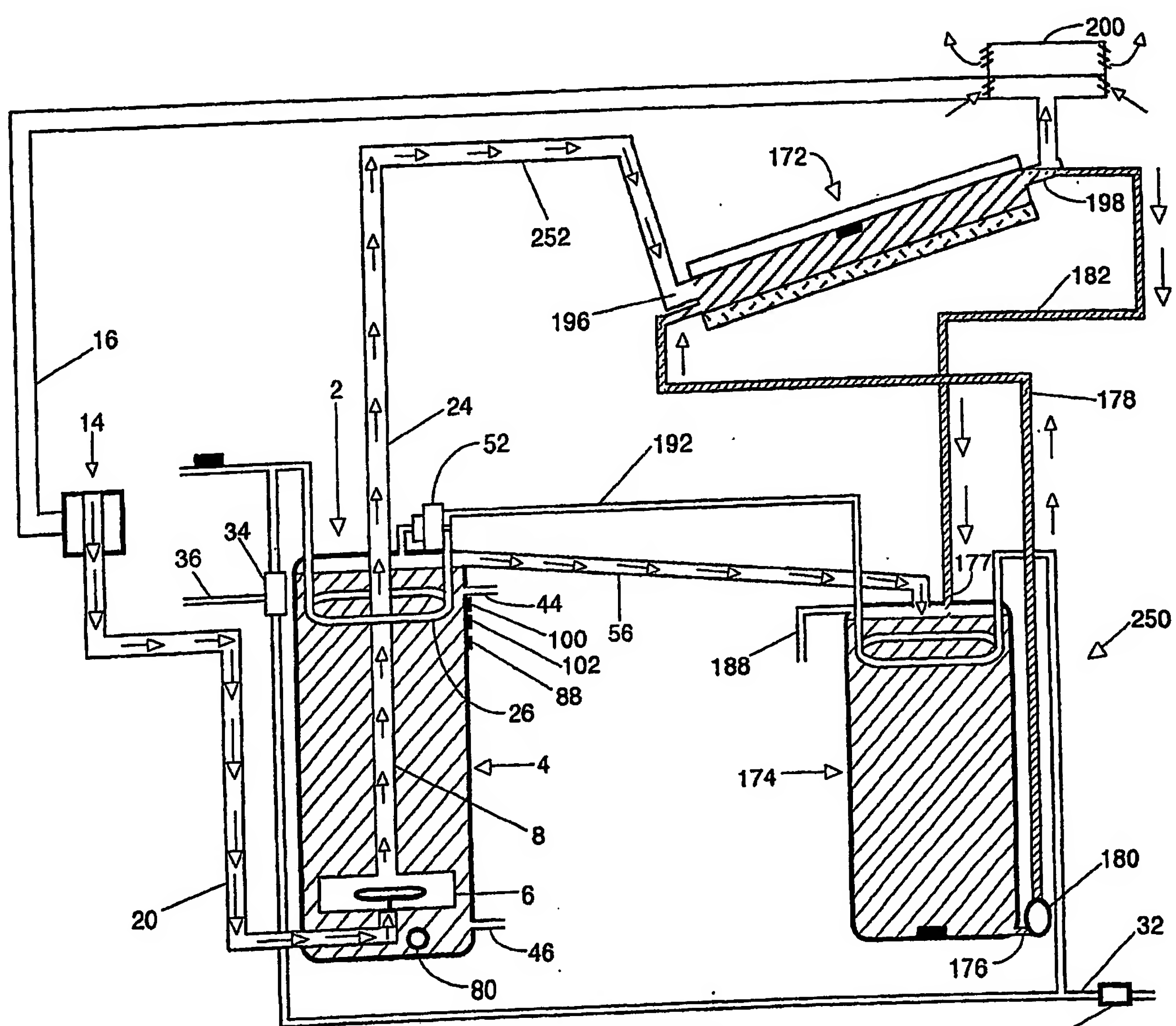
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FIG 13.

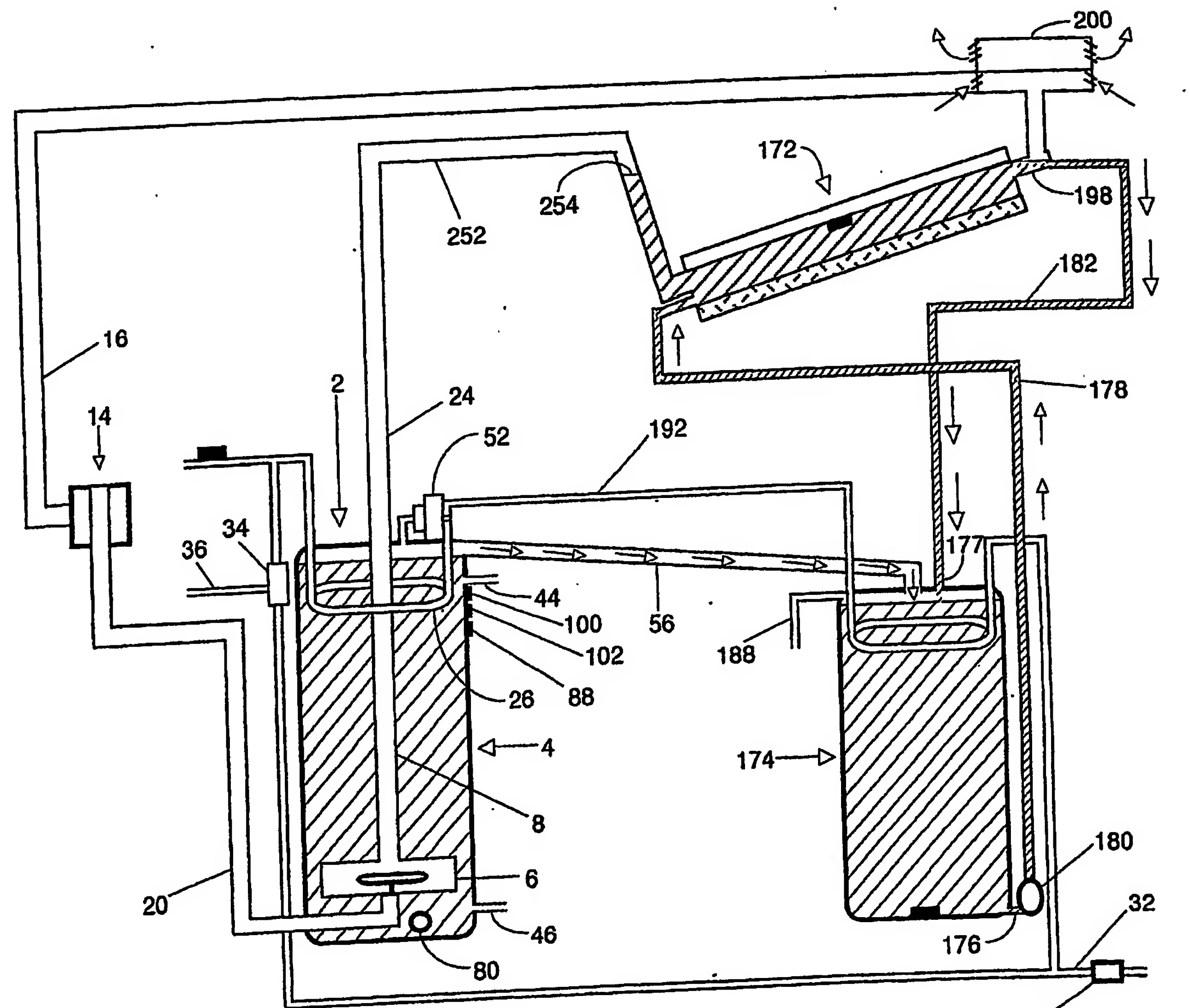
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FIG 14.

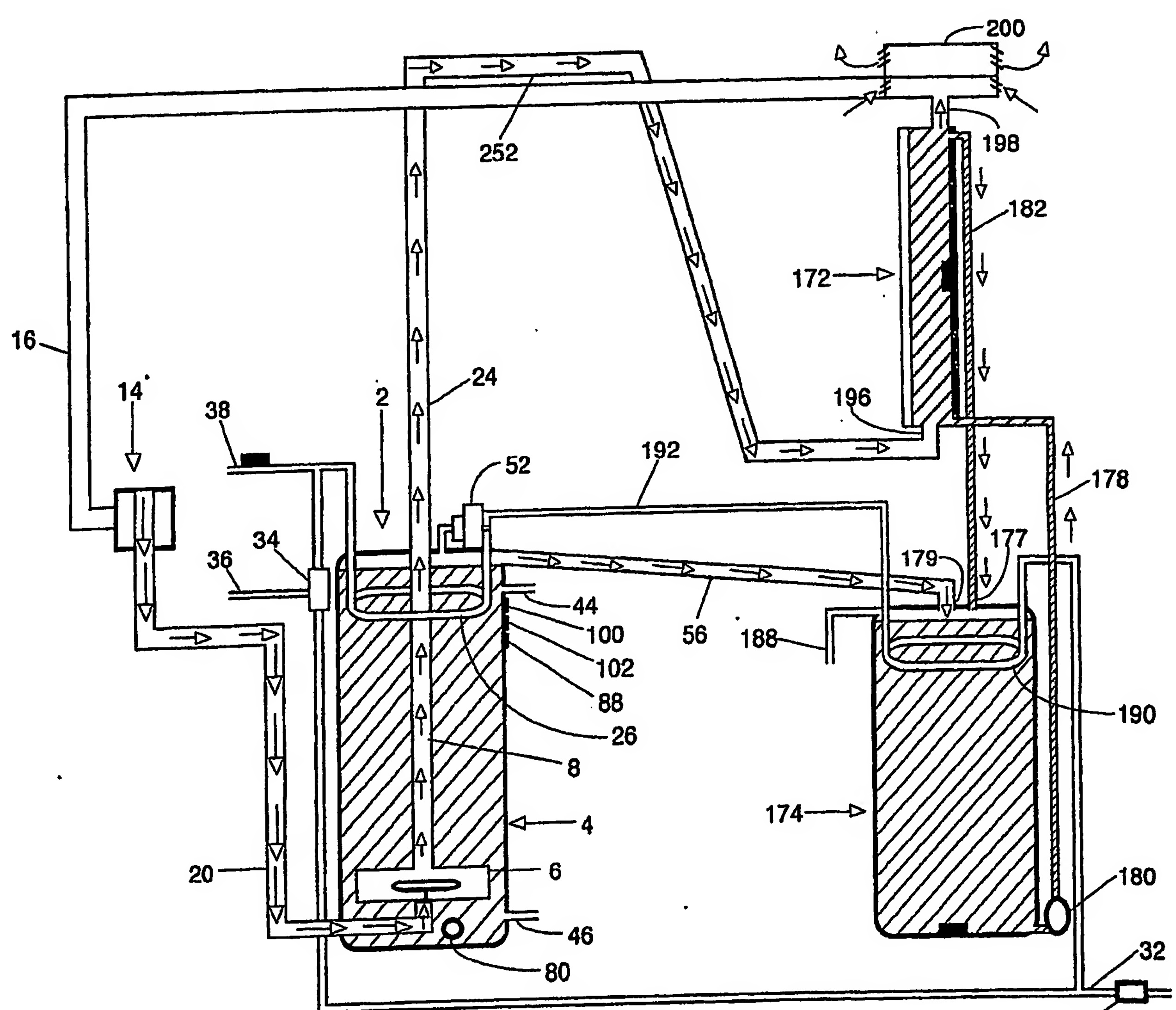
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FIG 15 A.

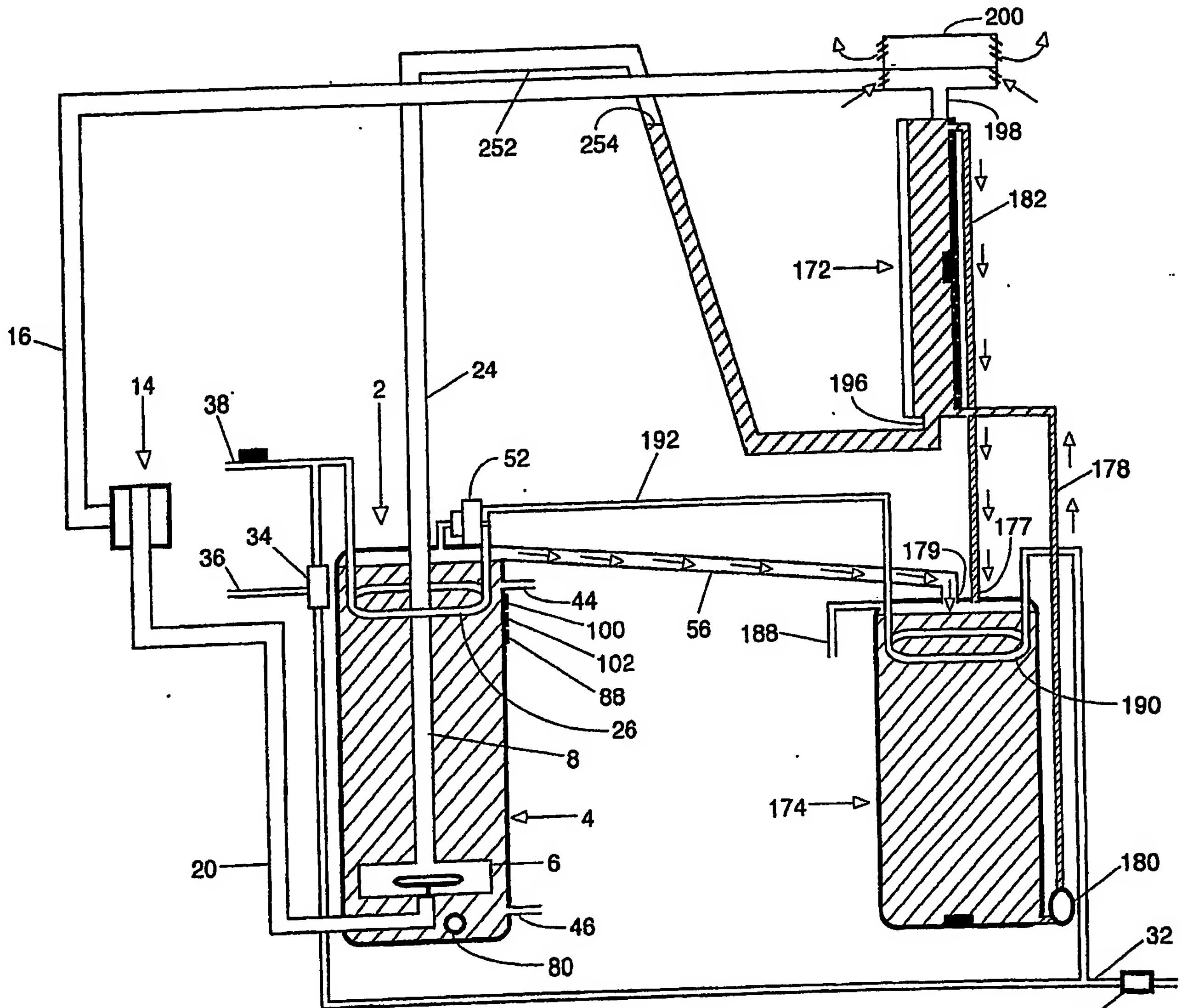
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FIG 15 B.

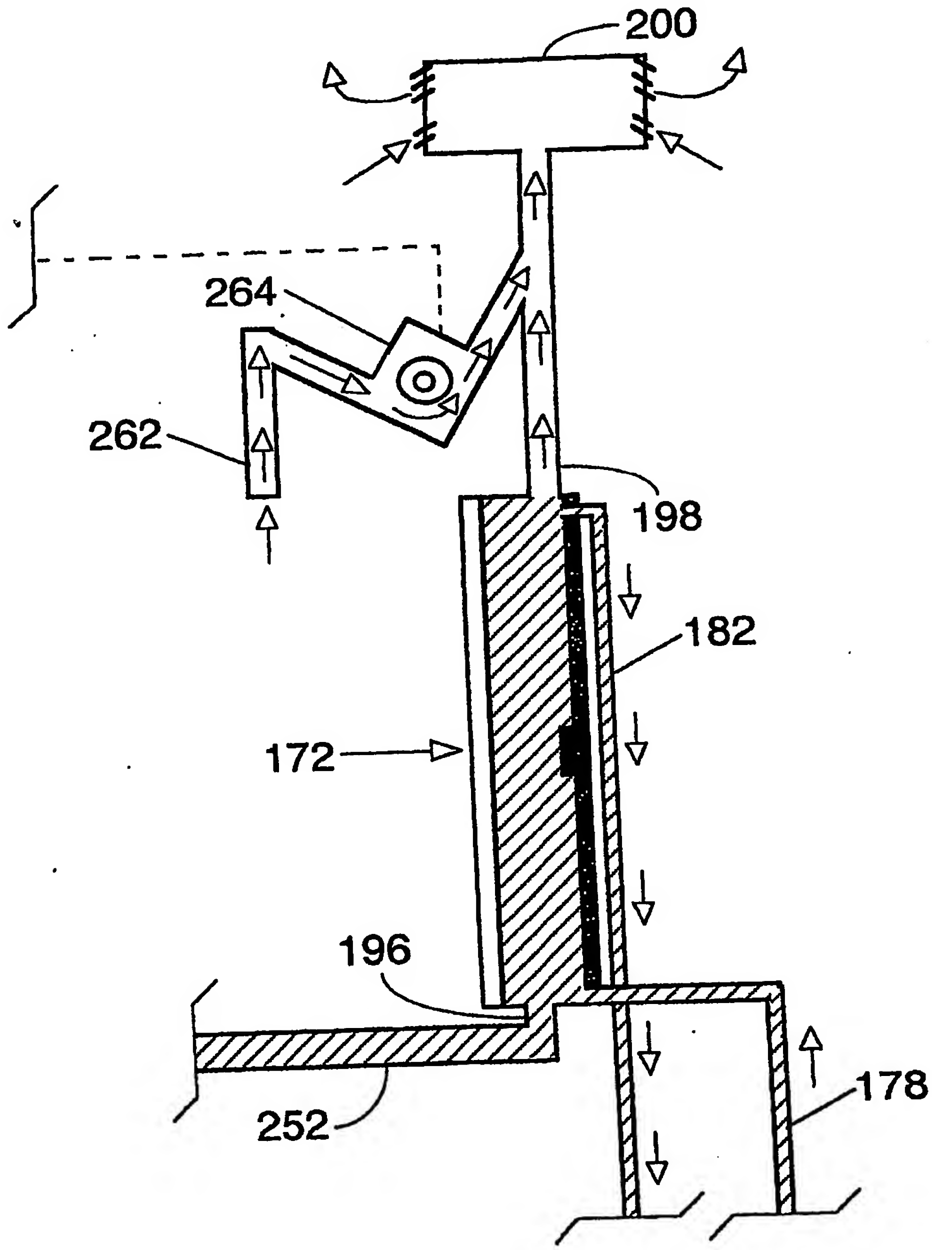

FIG 16 A.

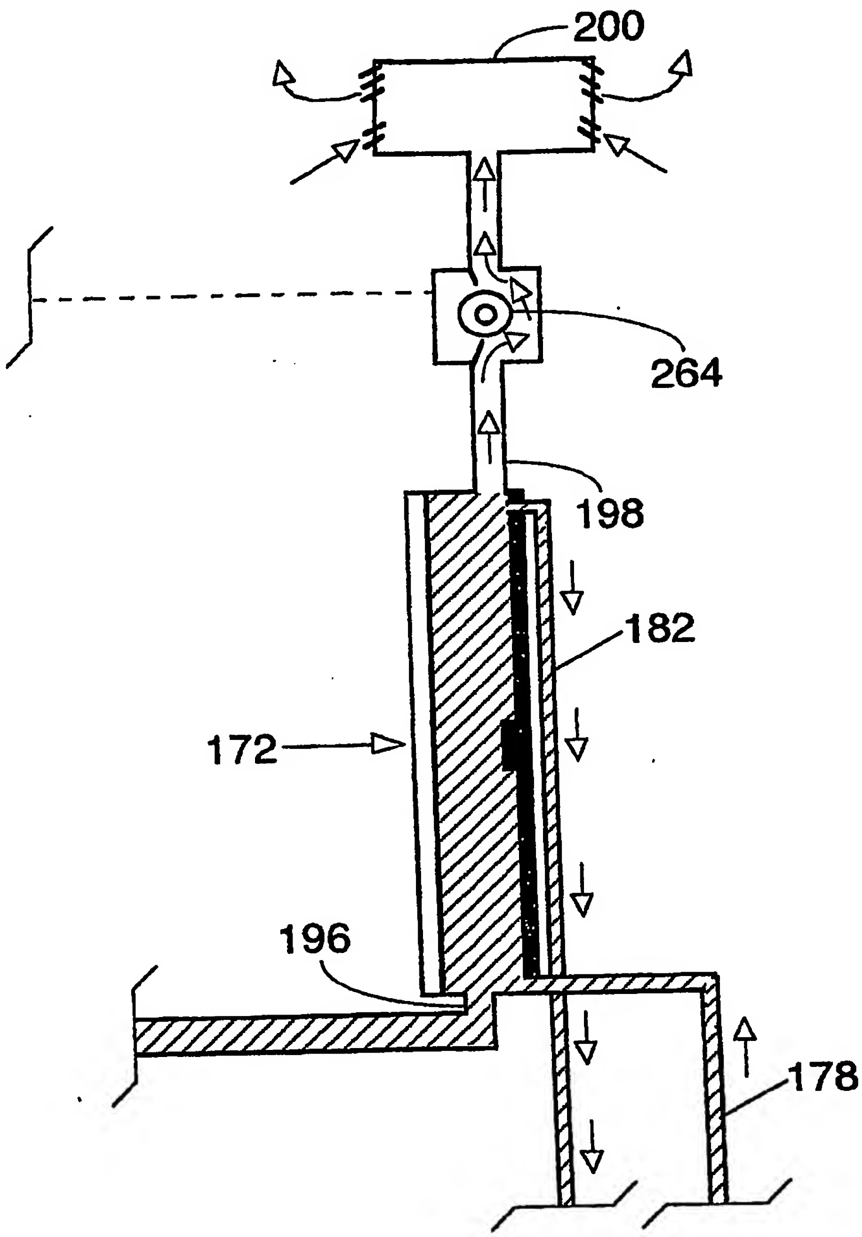

FIG 16 B.

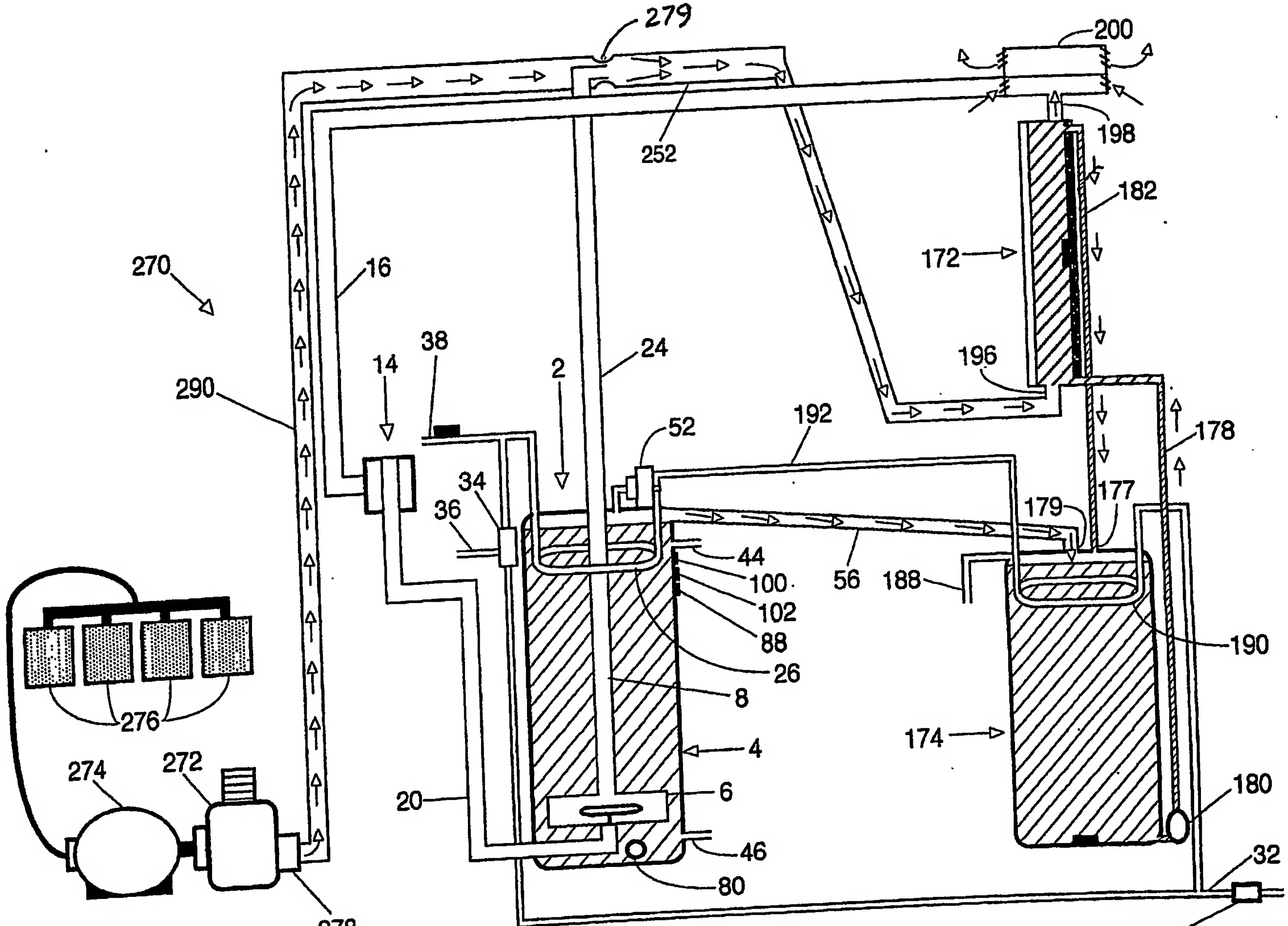

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FIG 17.

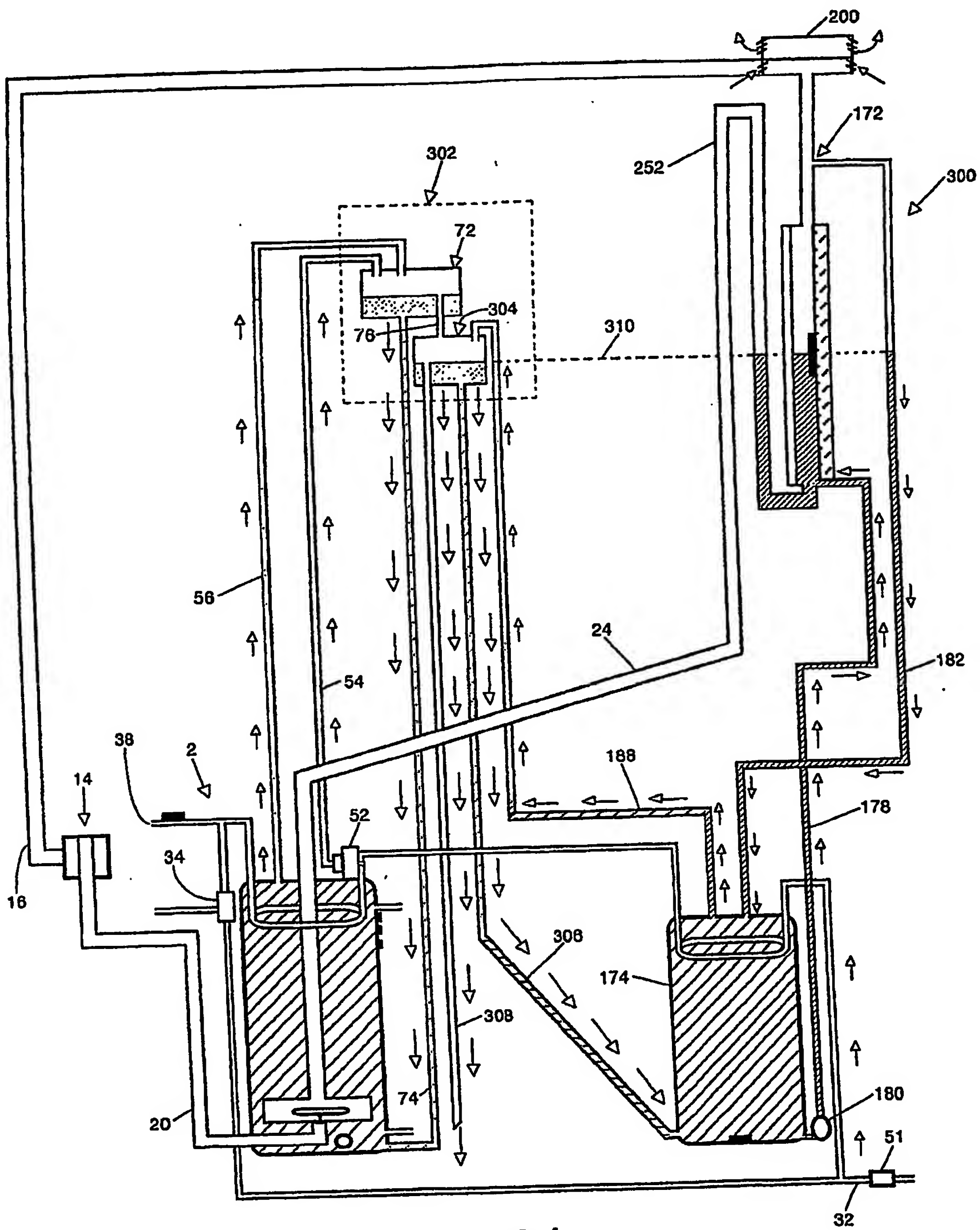
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FIG. 18 A

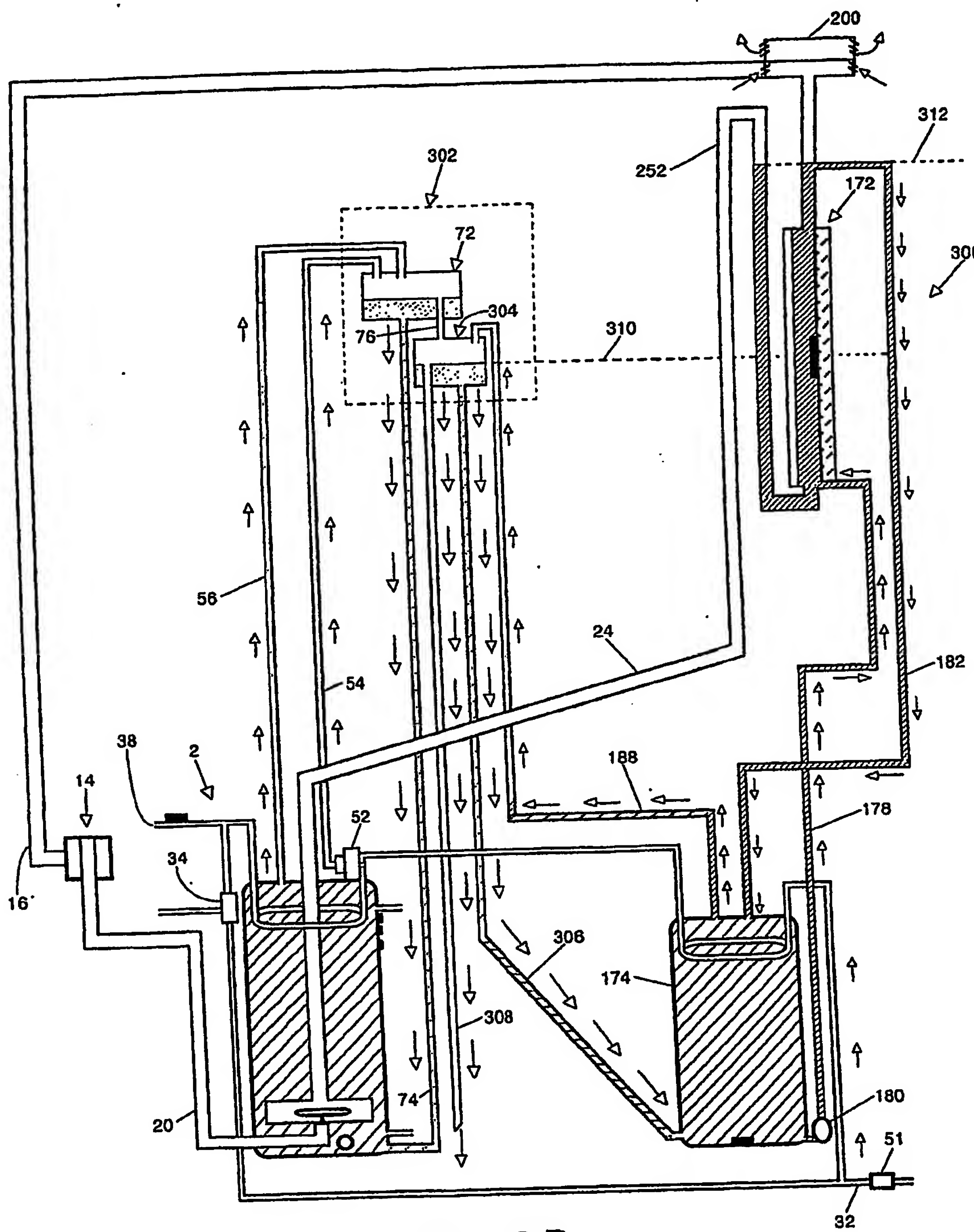
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FIG. 18 B

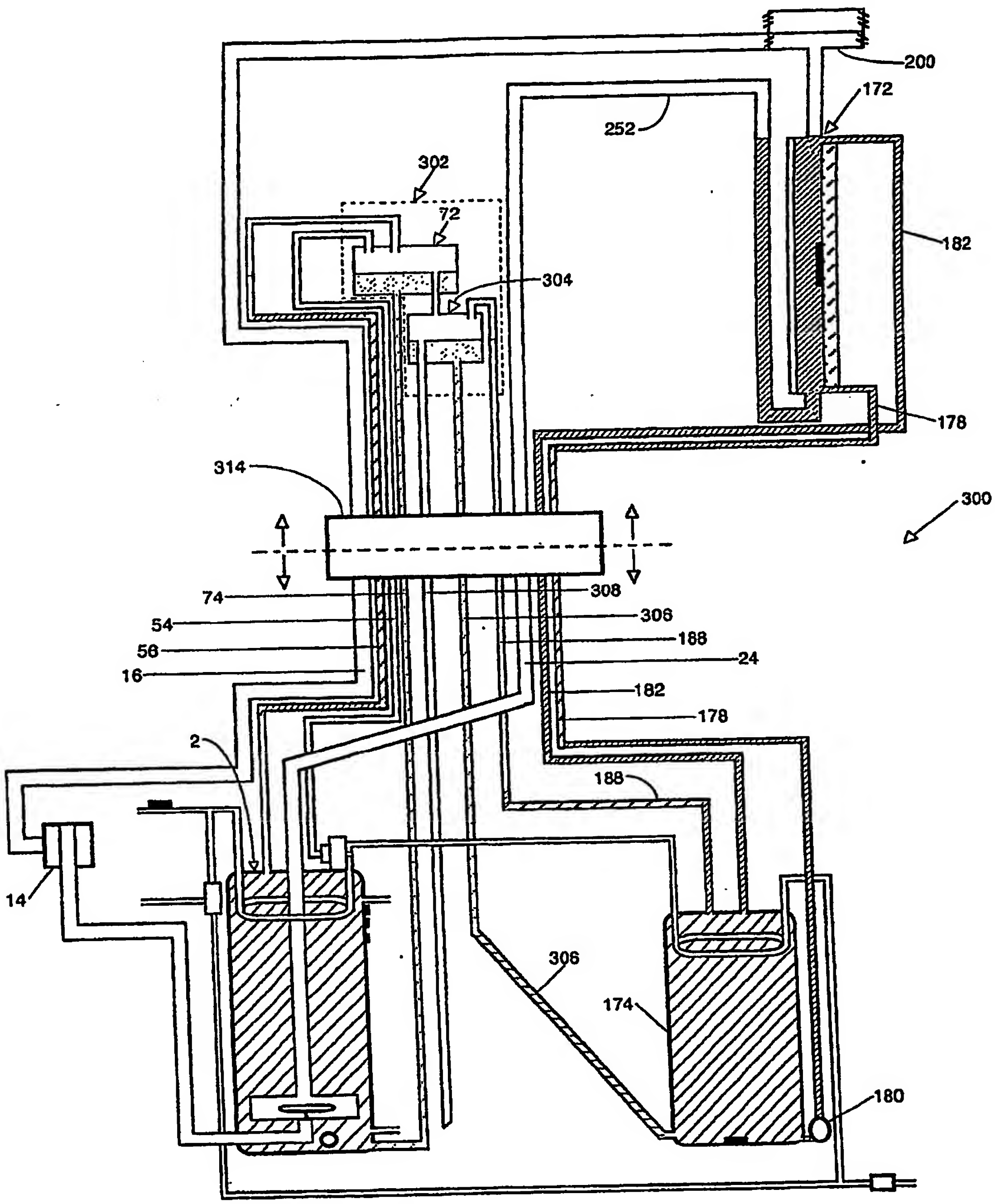
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FIG. 19.

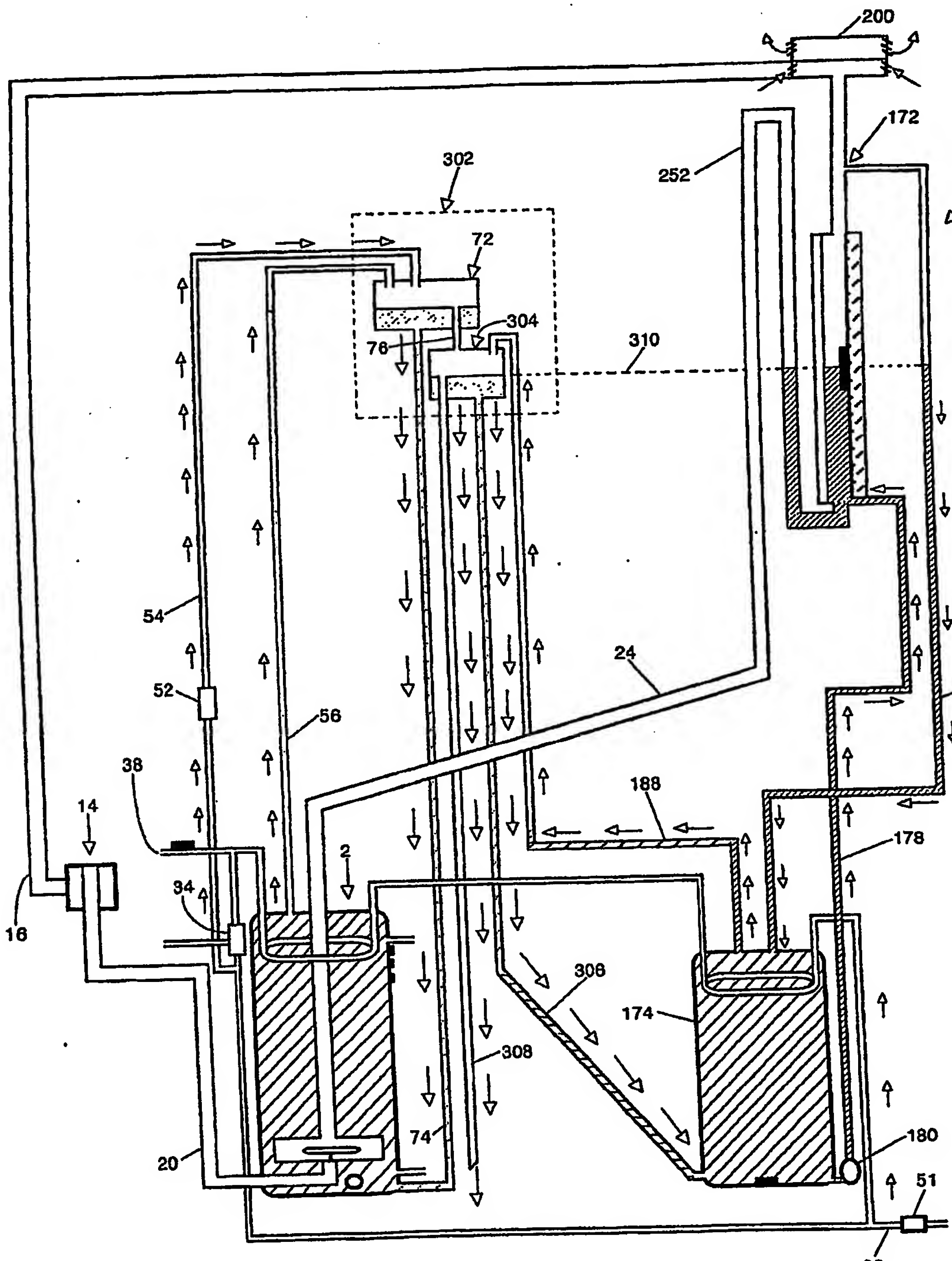
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FIG. 20

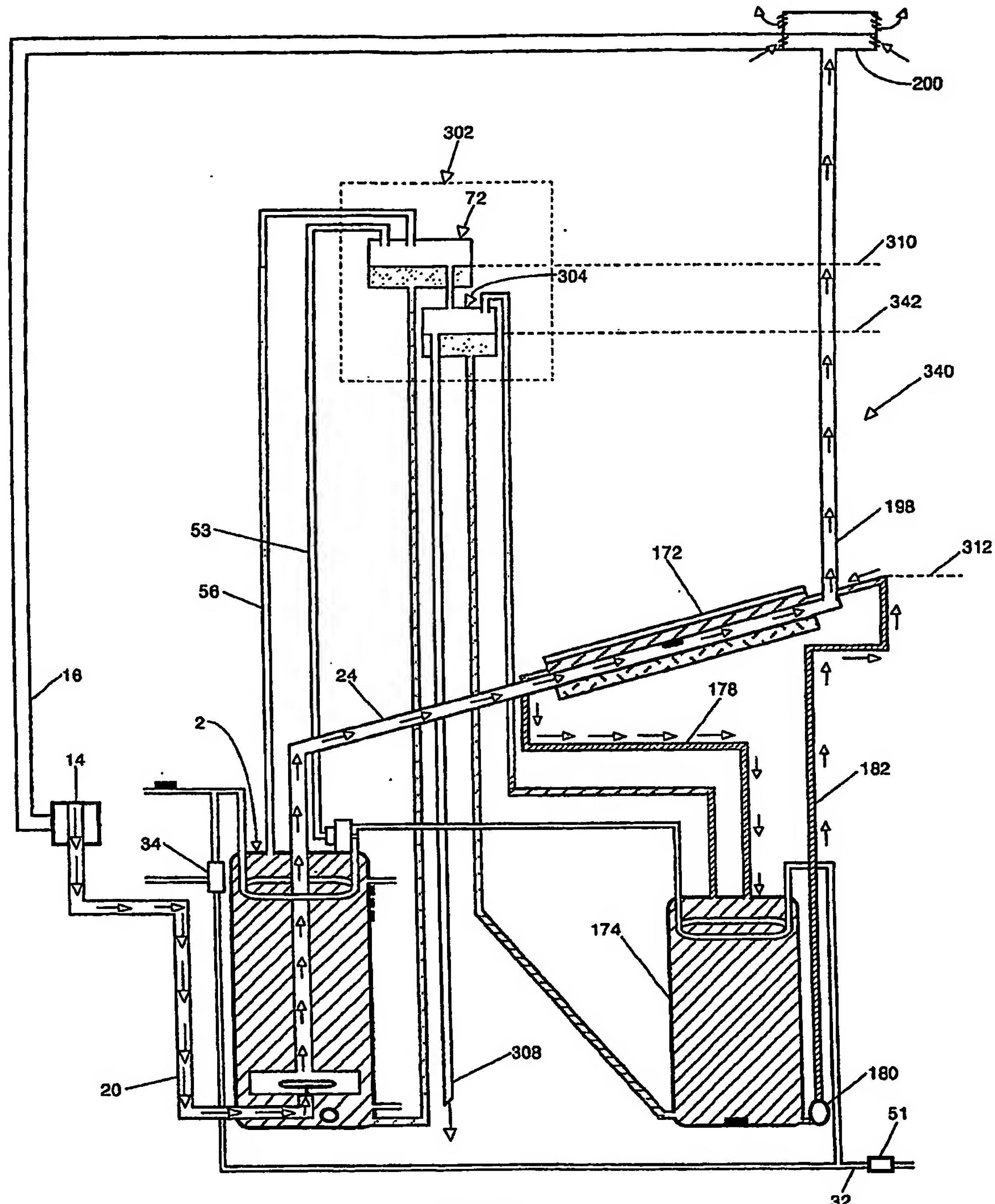
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FIG. 21

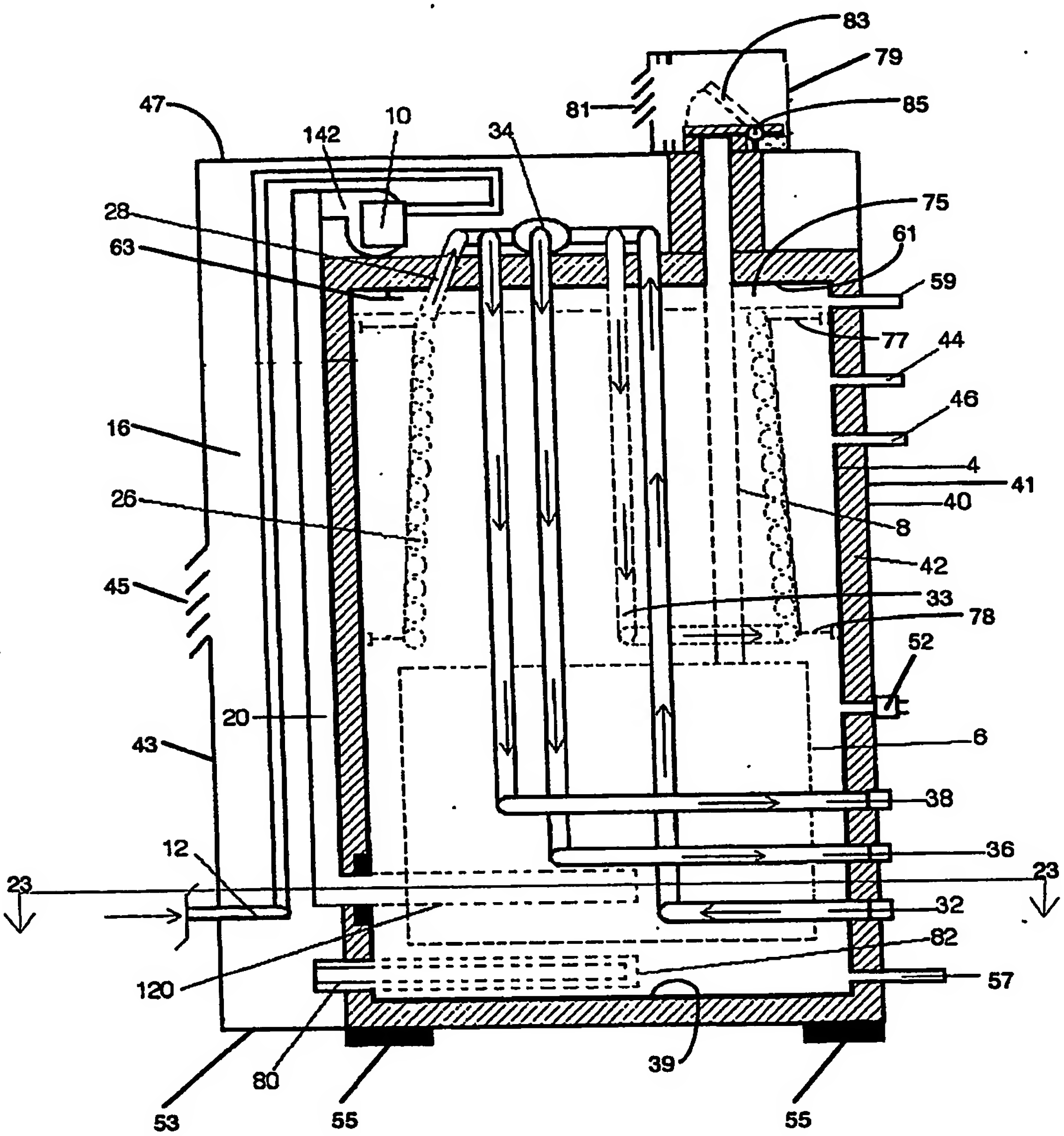
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FIG 22

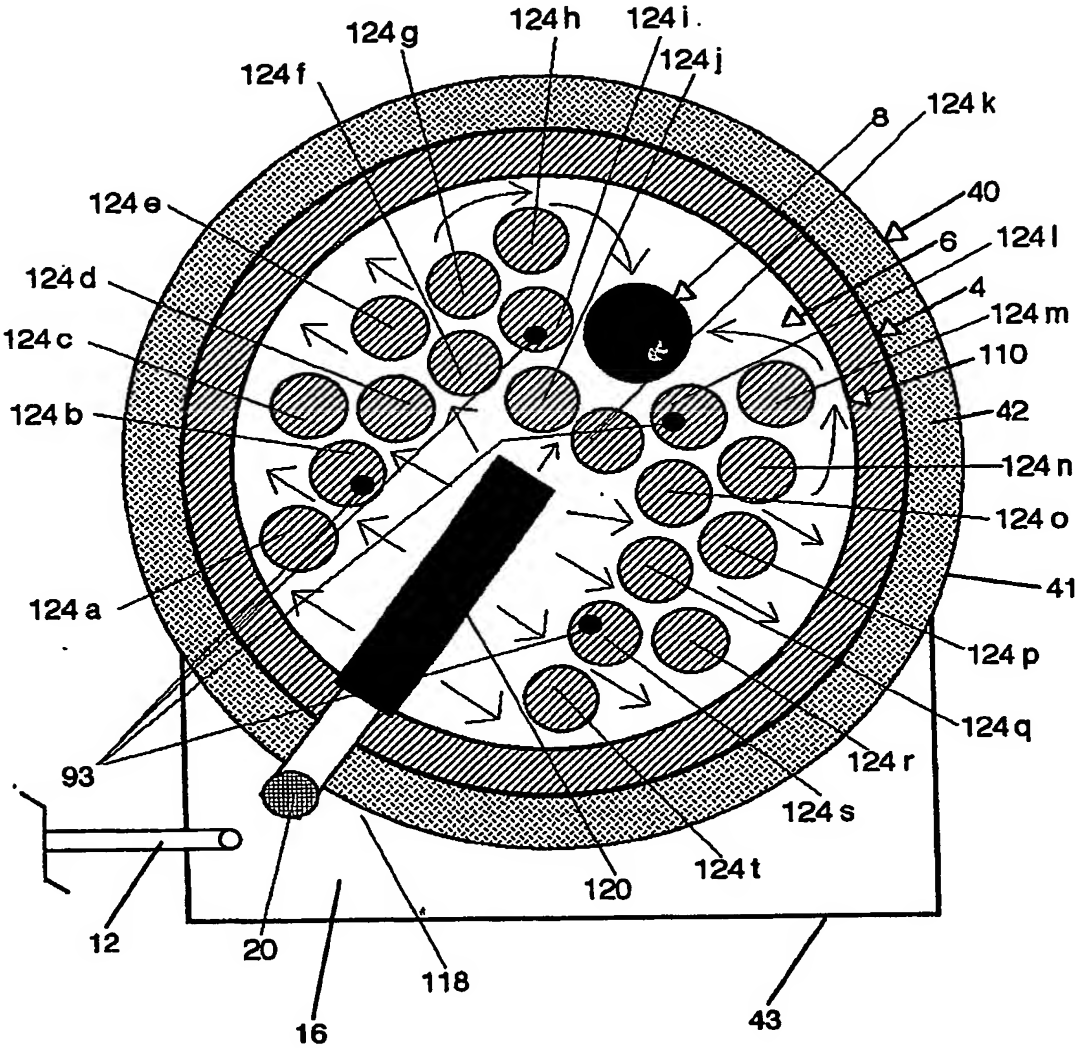

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FIG 23

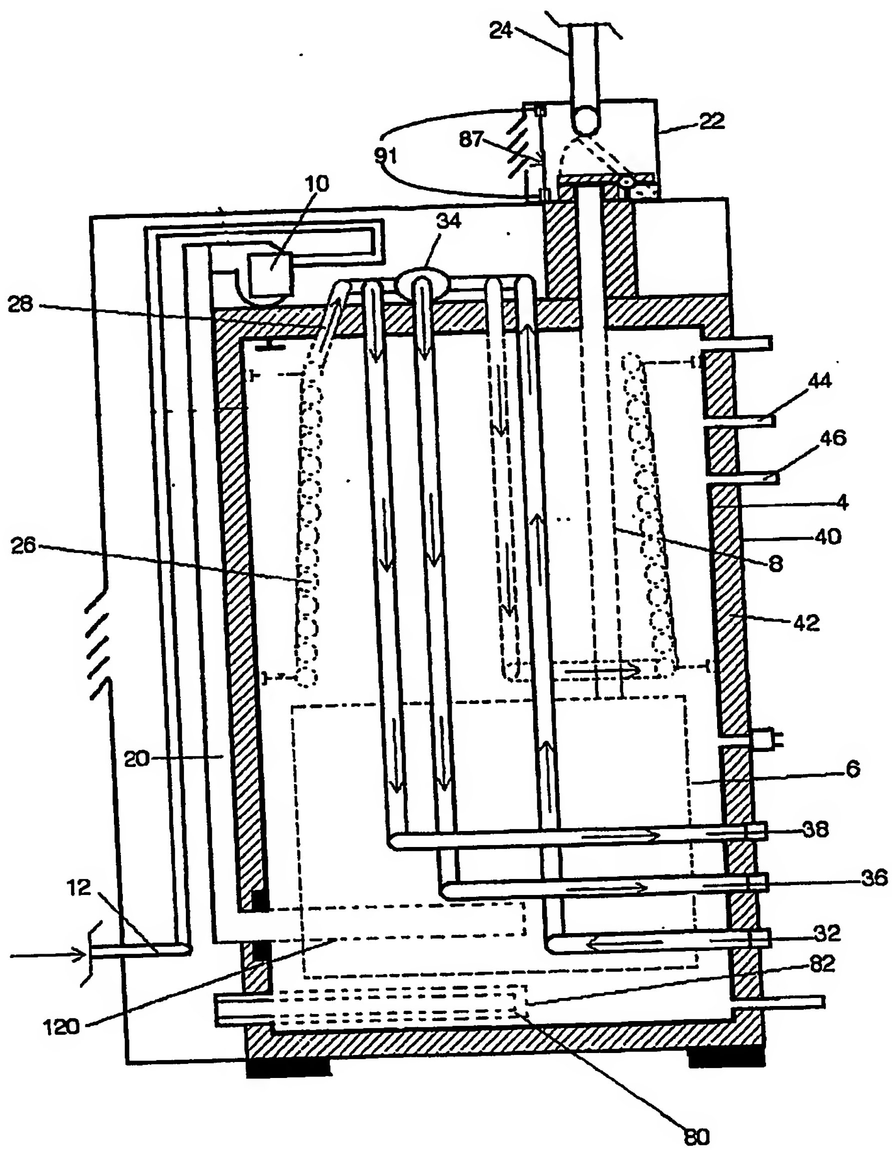

FIG 24

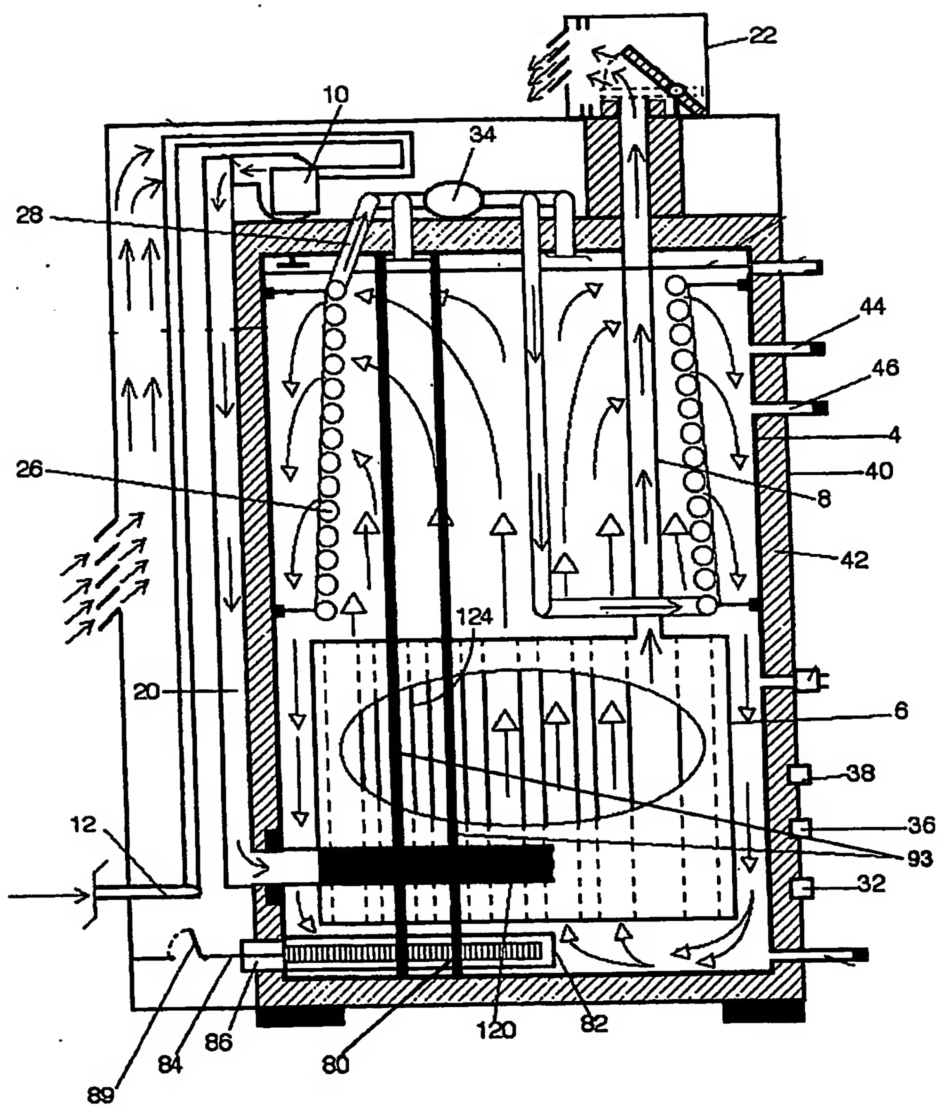

FIG 25

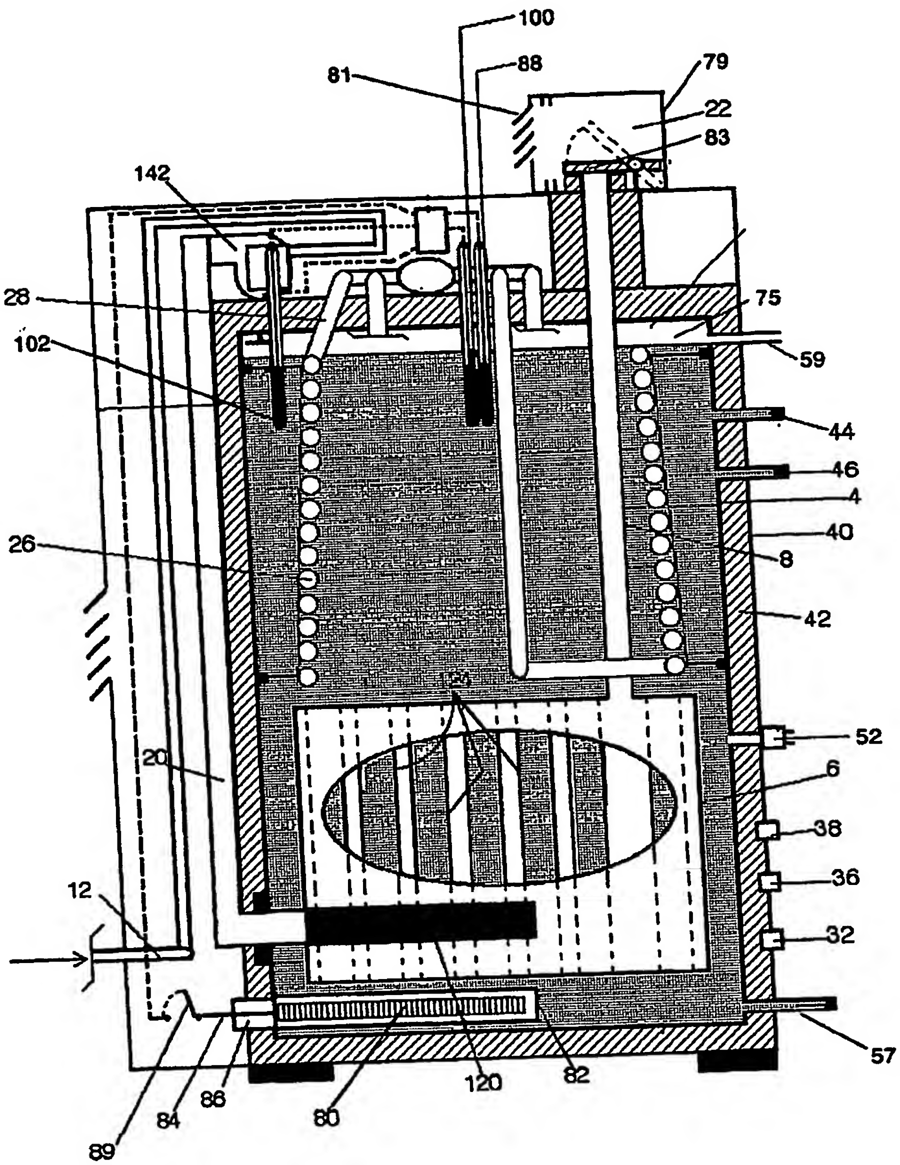

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FIG 26

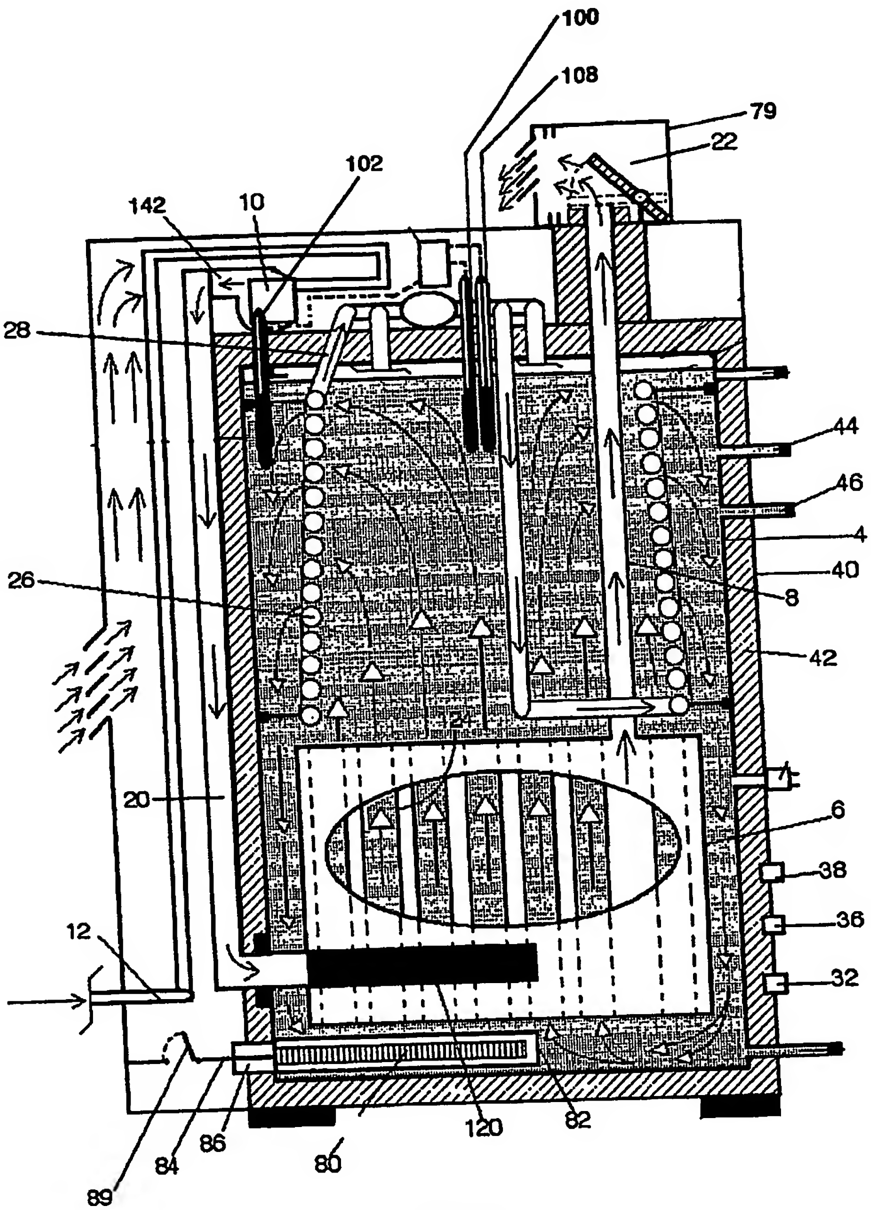
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FIG 27

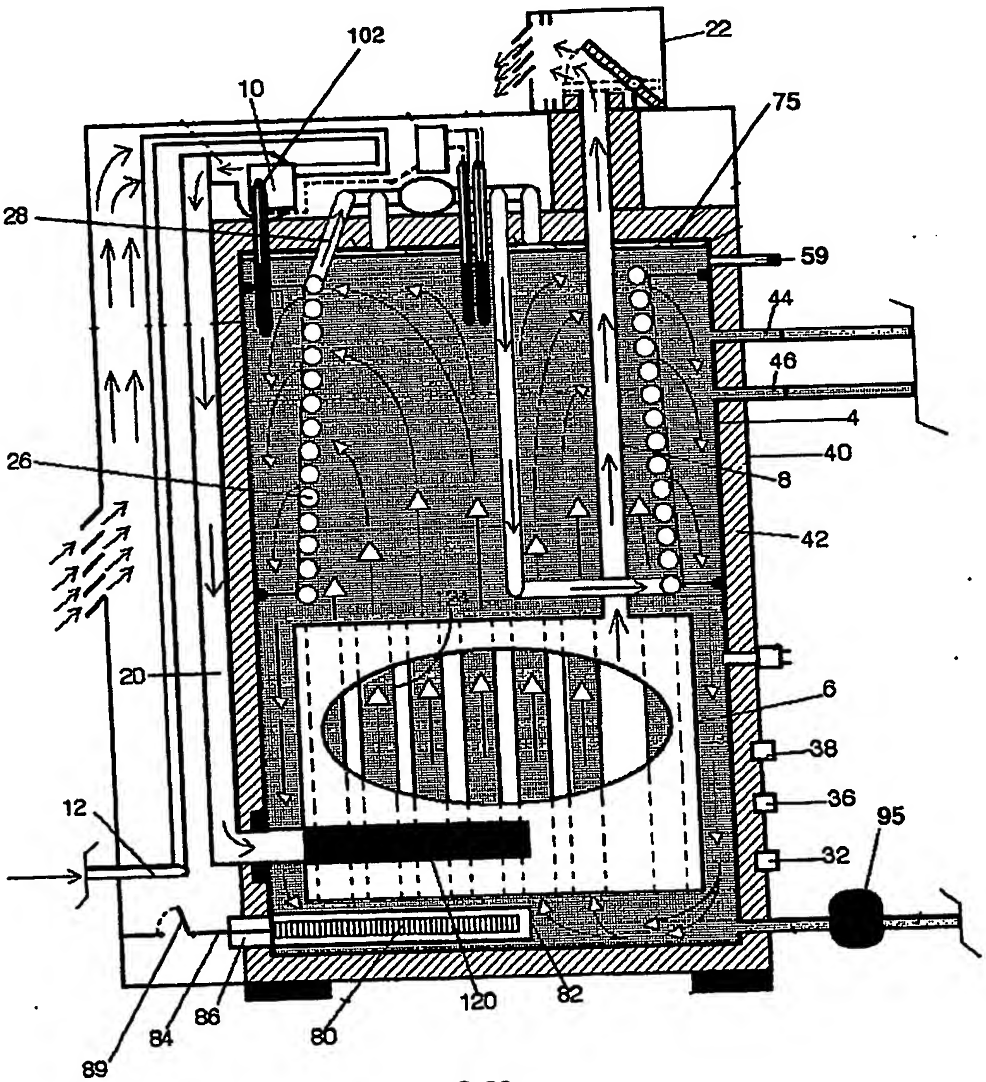

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FIG 28

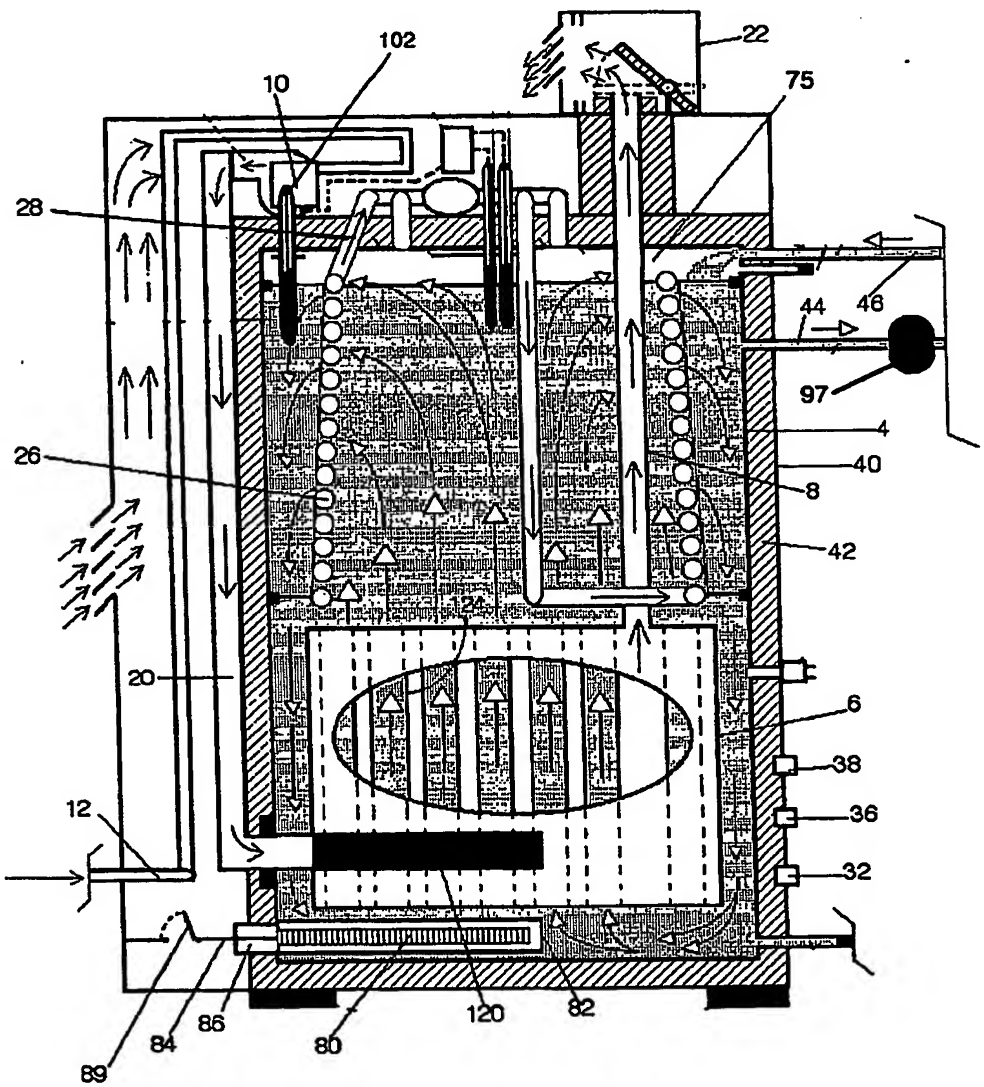

FIG 29

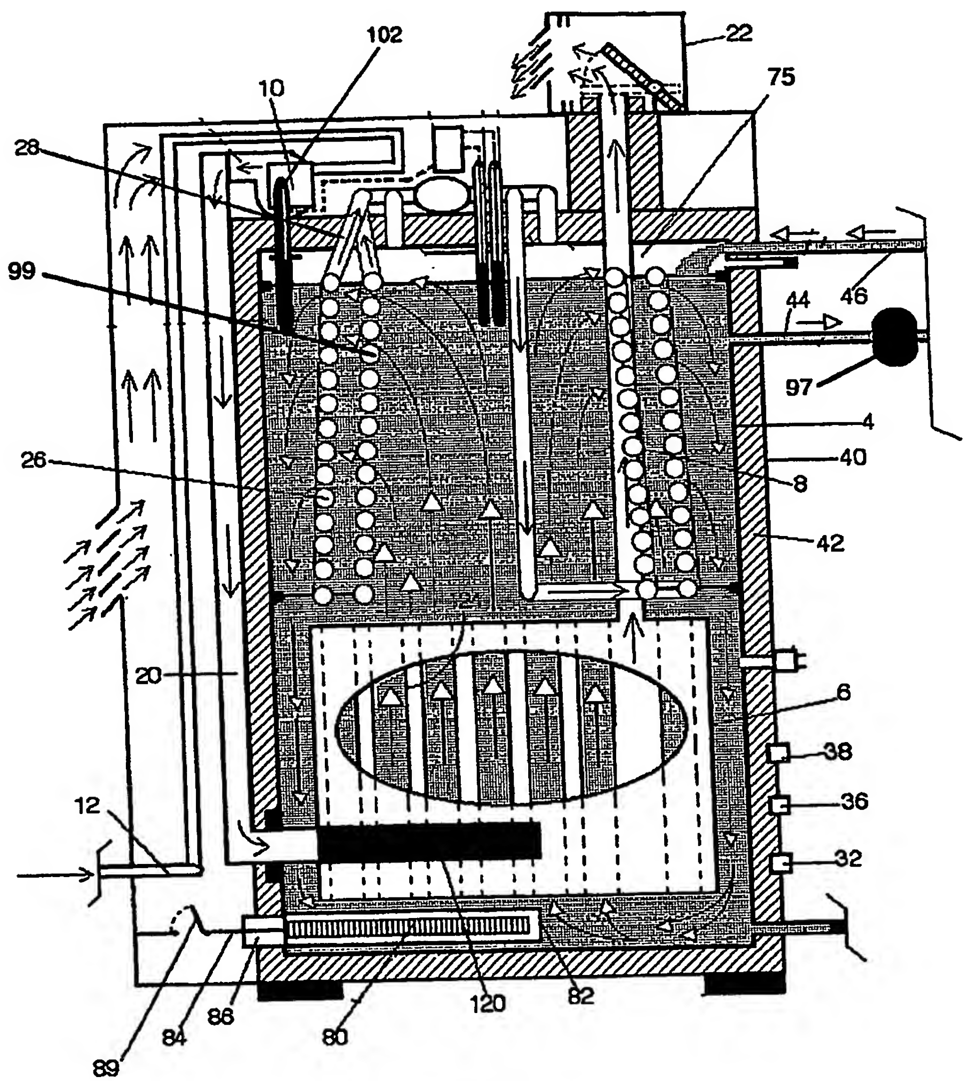

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FIG 30

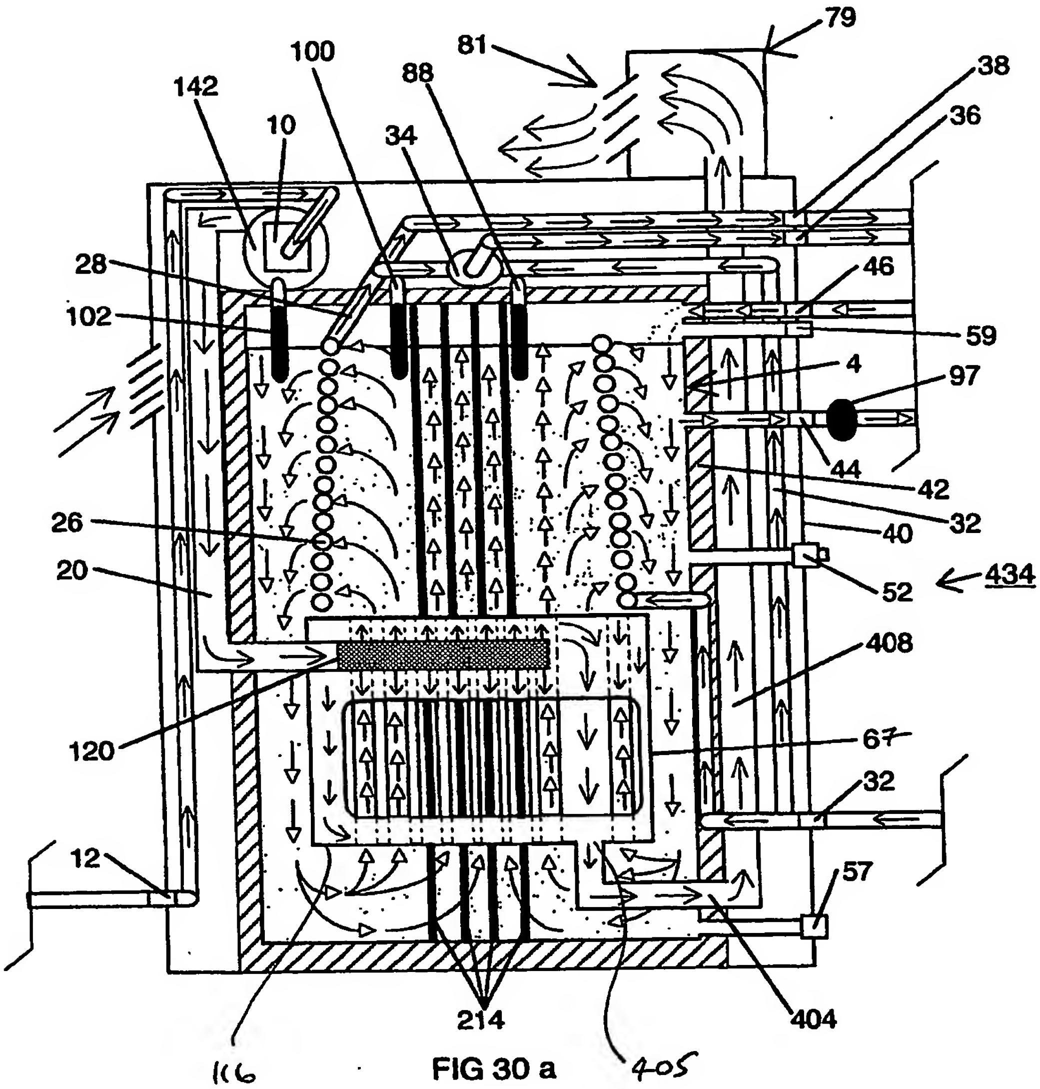
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FIG 30 a

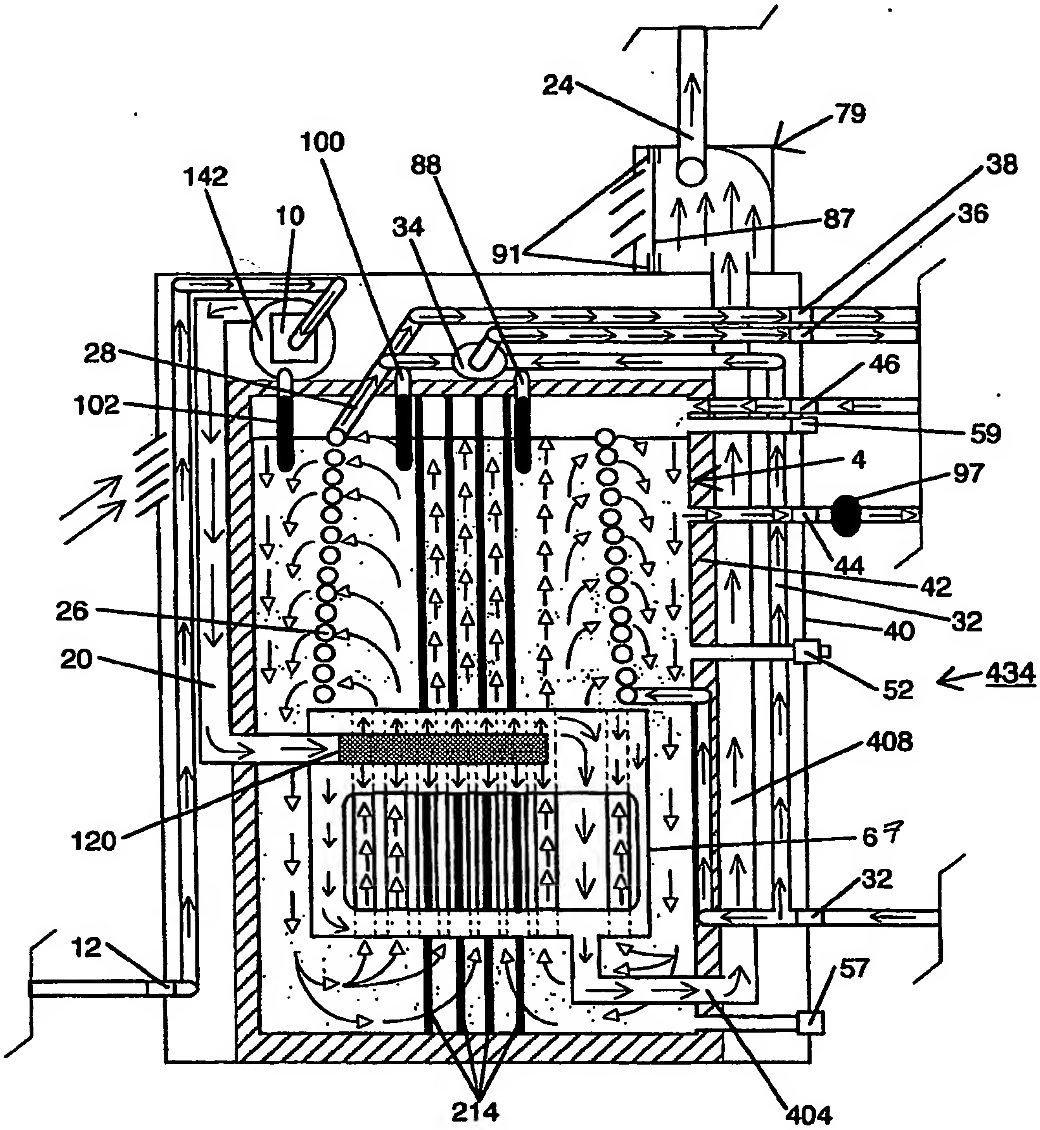
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FIG 30 b

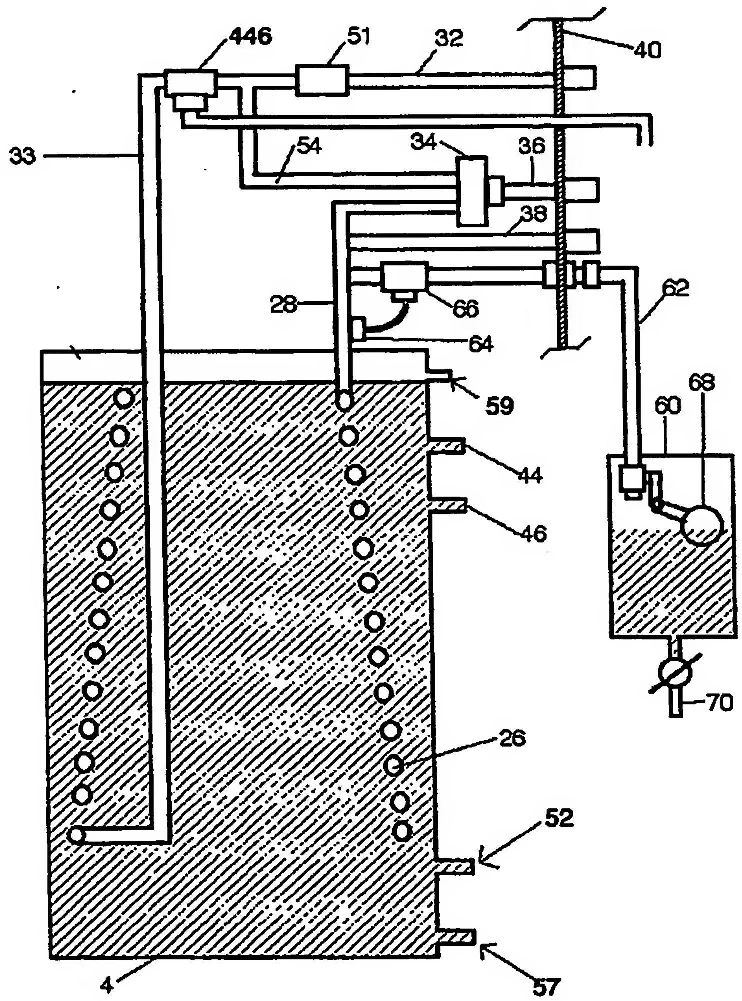

FIG 31

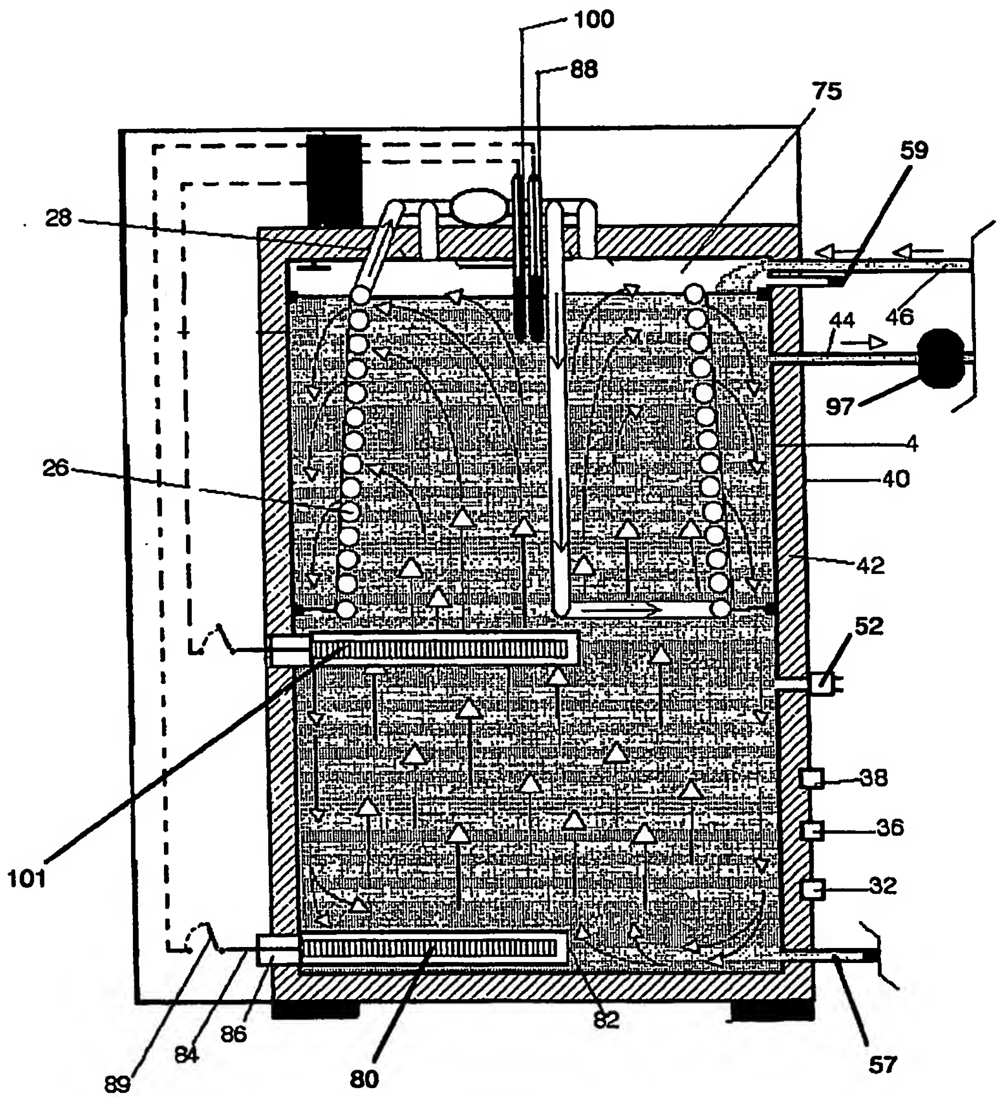

FIG 32

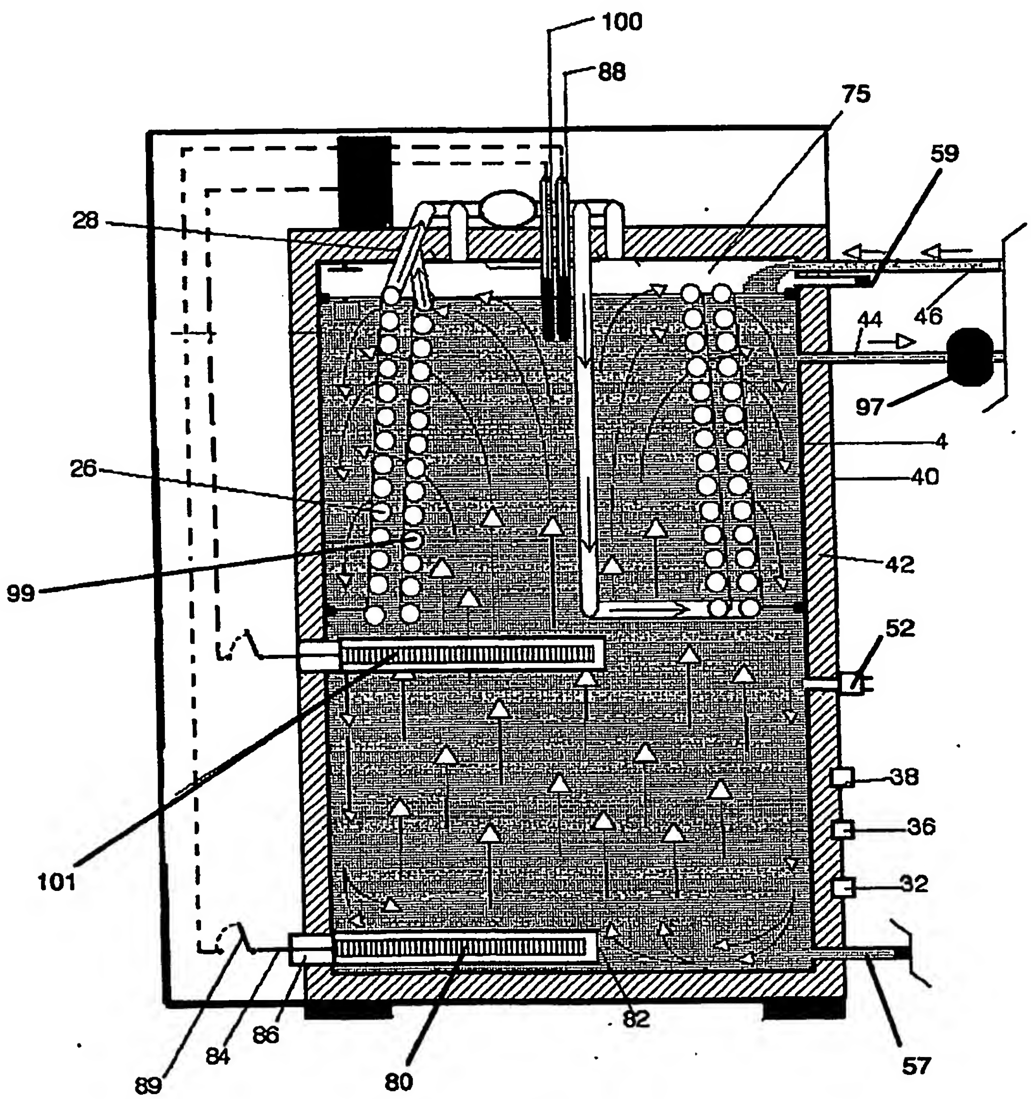

FIG 33

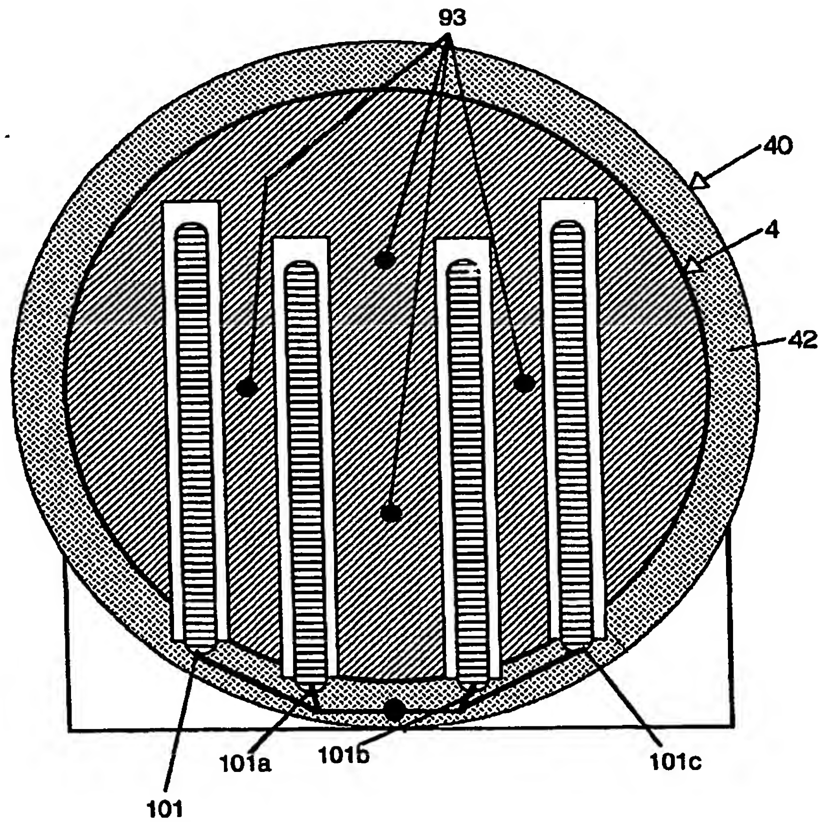

FIG 34

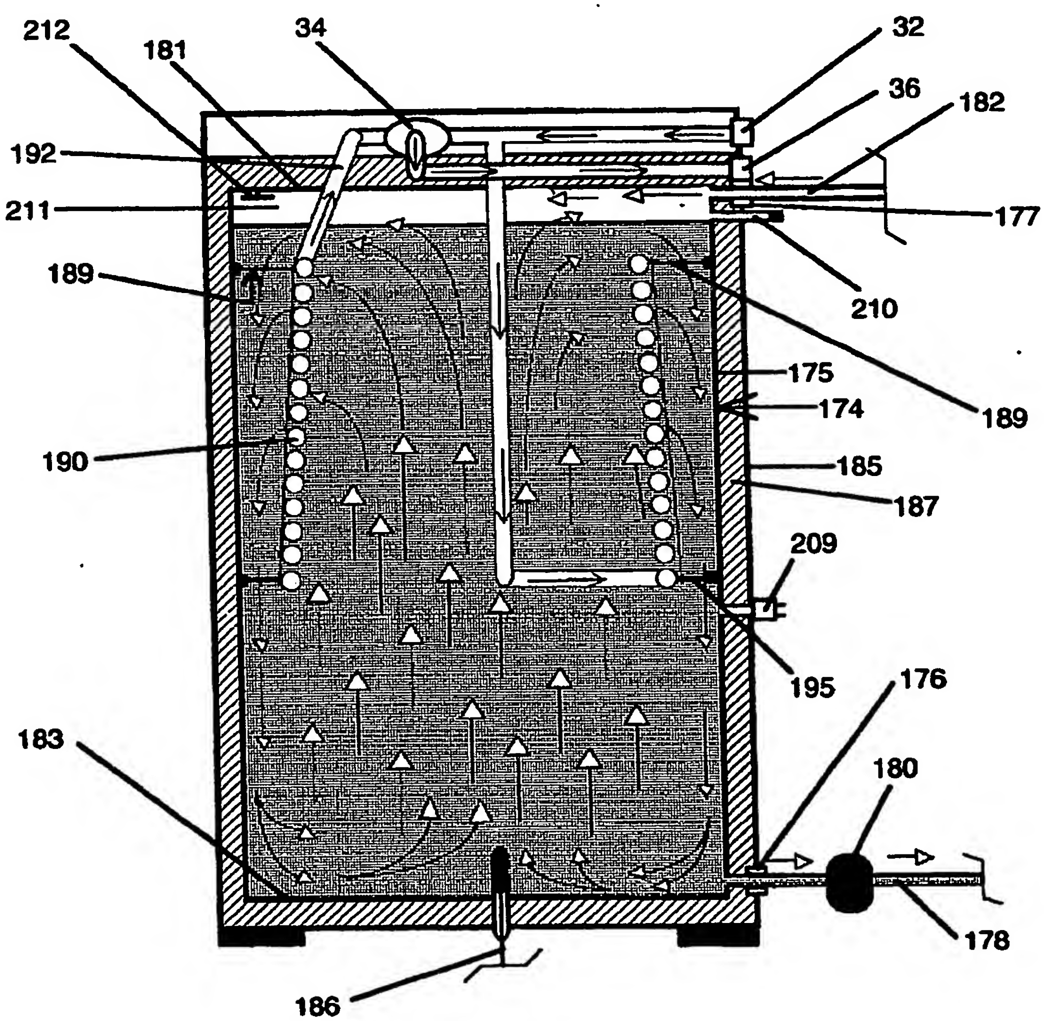
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FIG 35

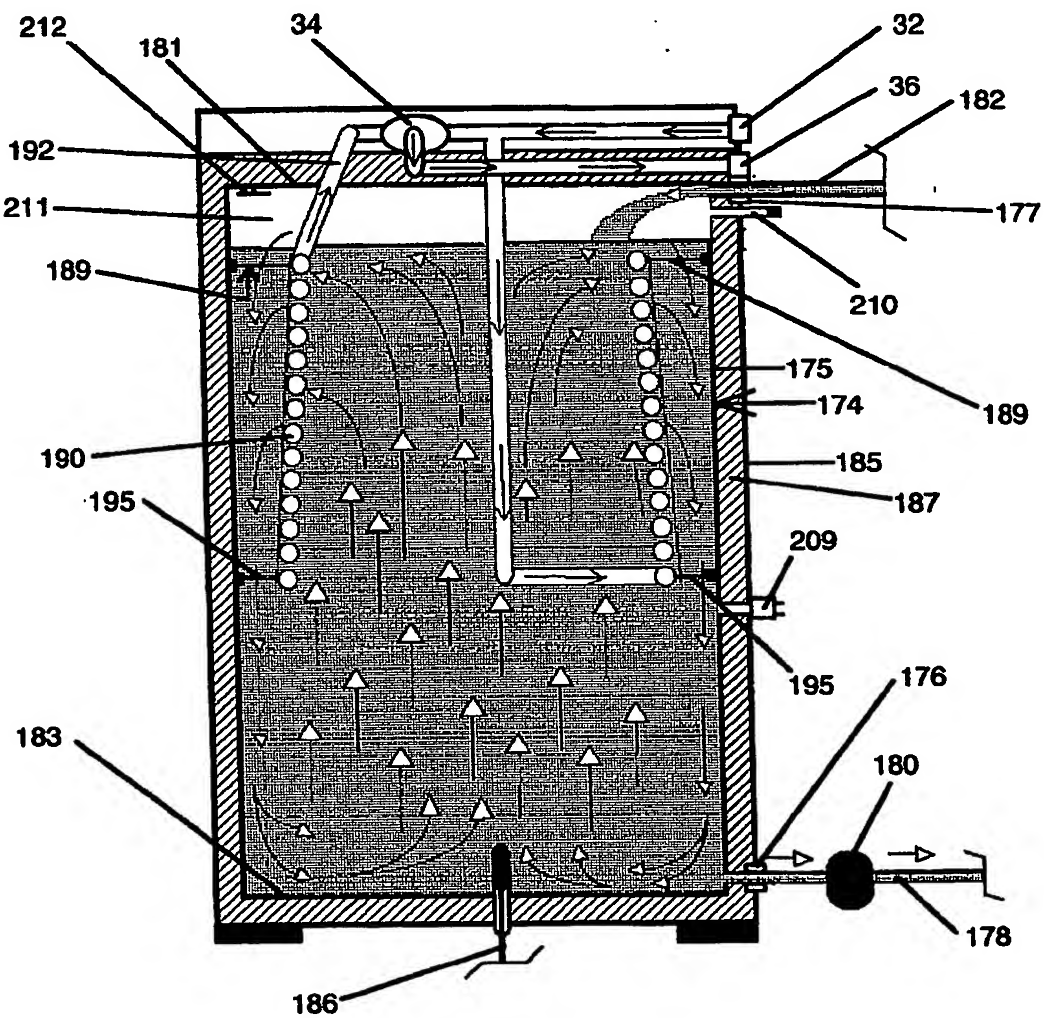
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FIG 36

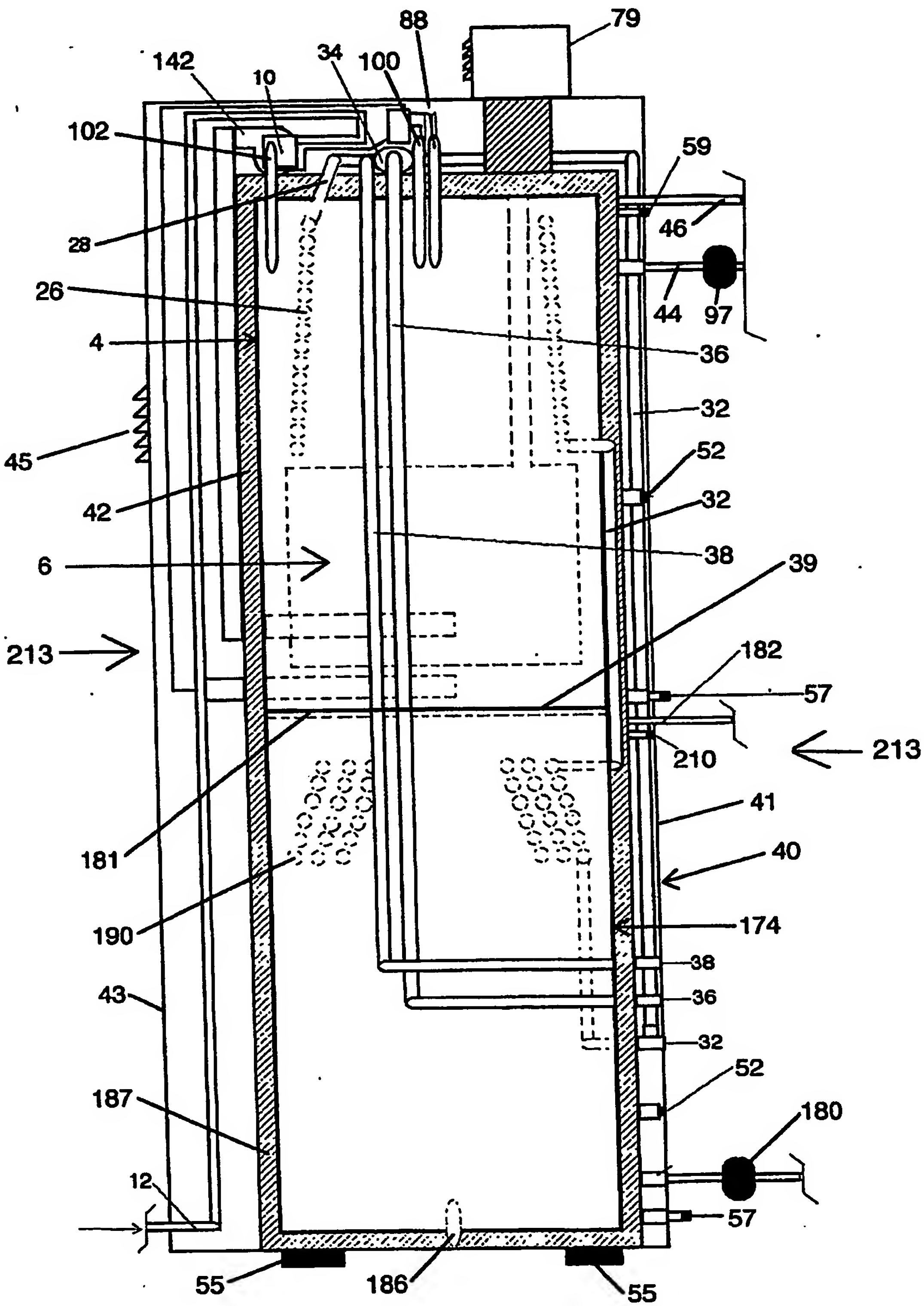

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FIG 37

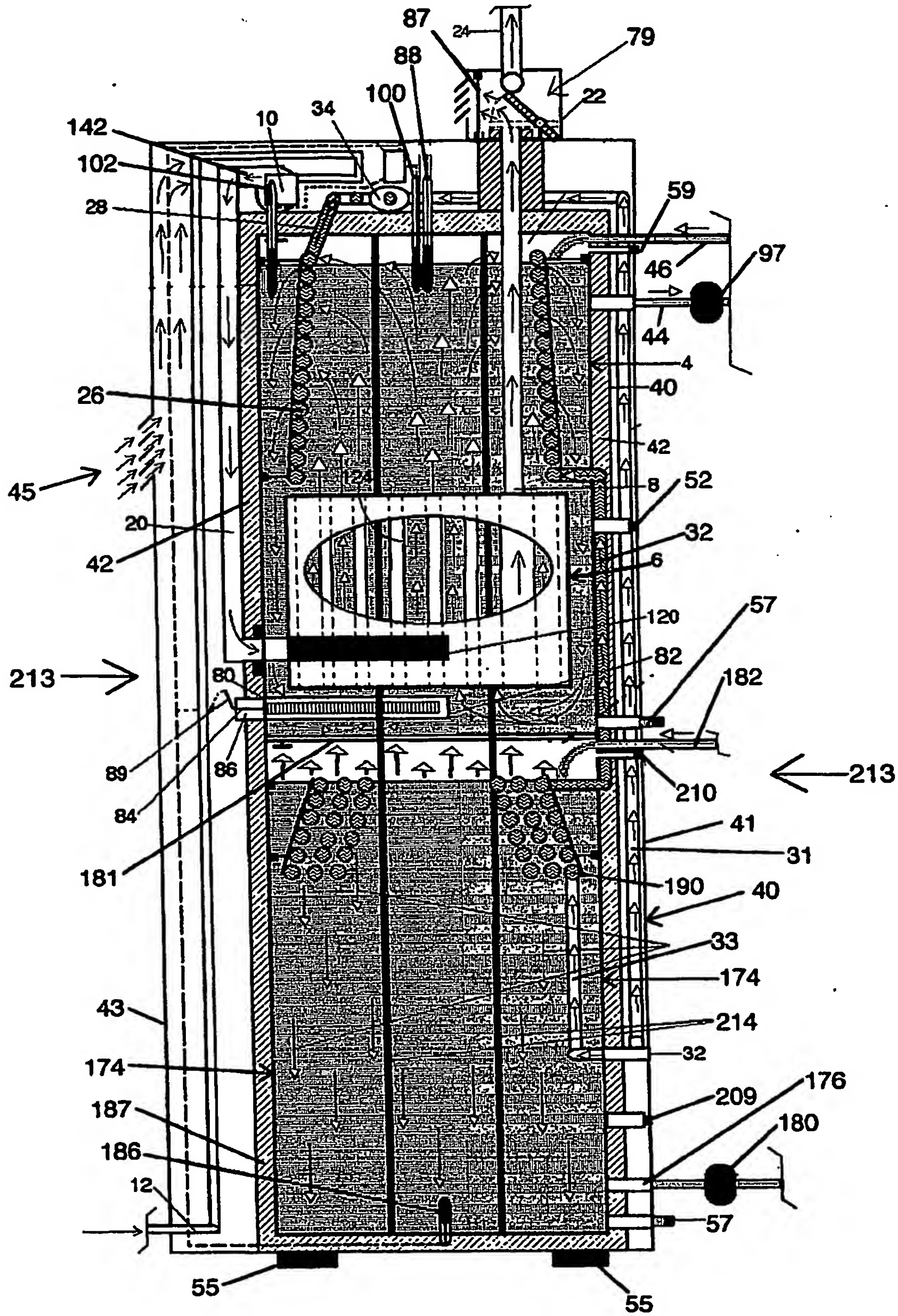
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FIG 38

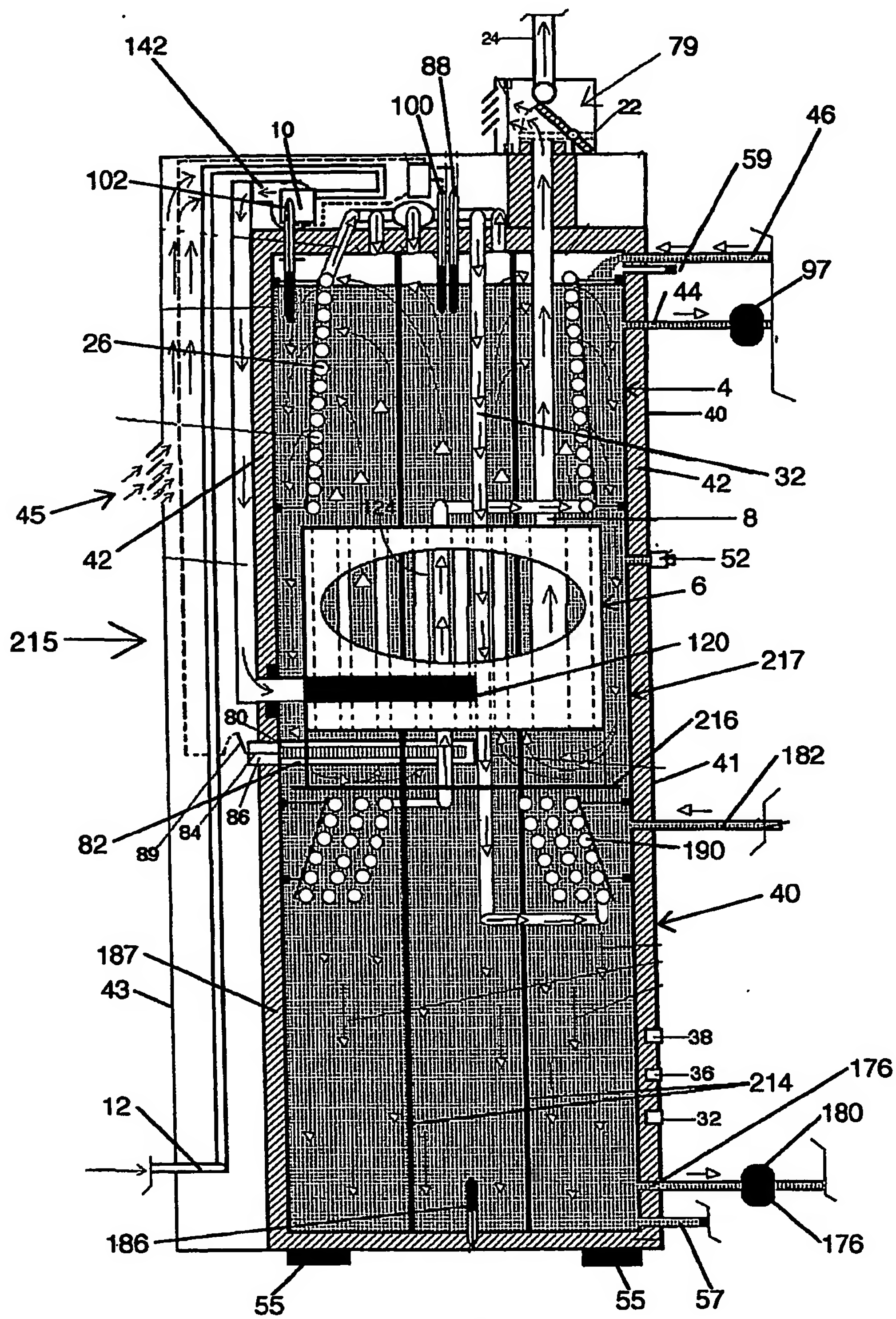

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FIG 39

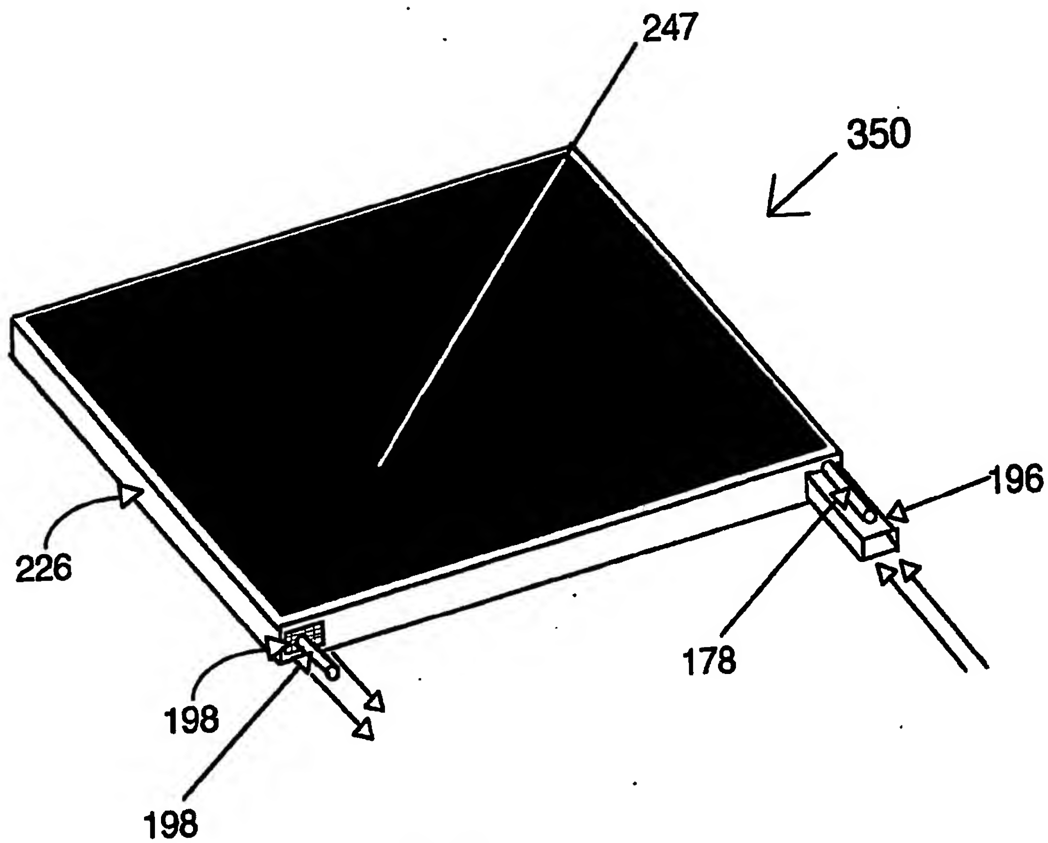

FIG 40

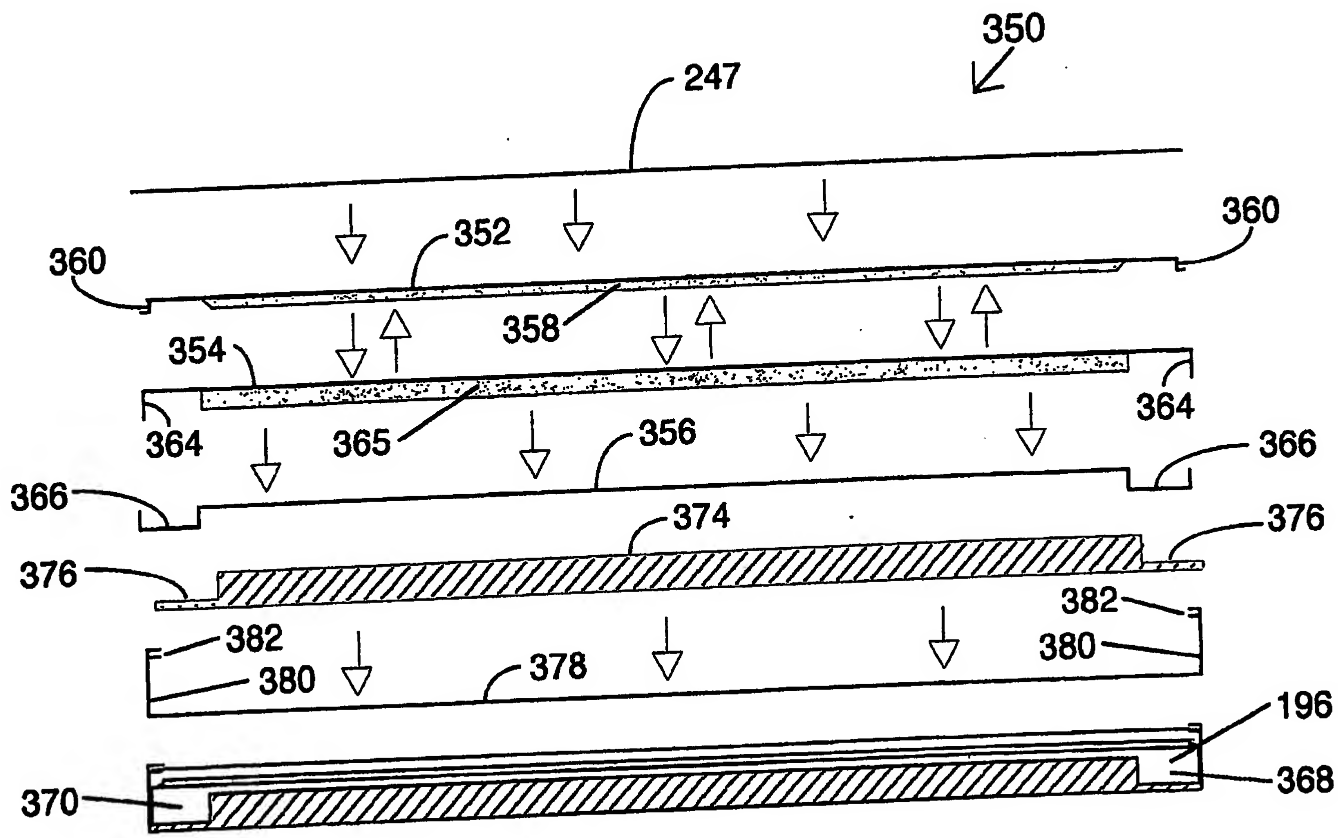
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FIG 41

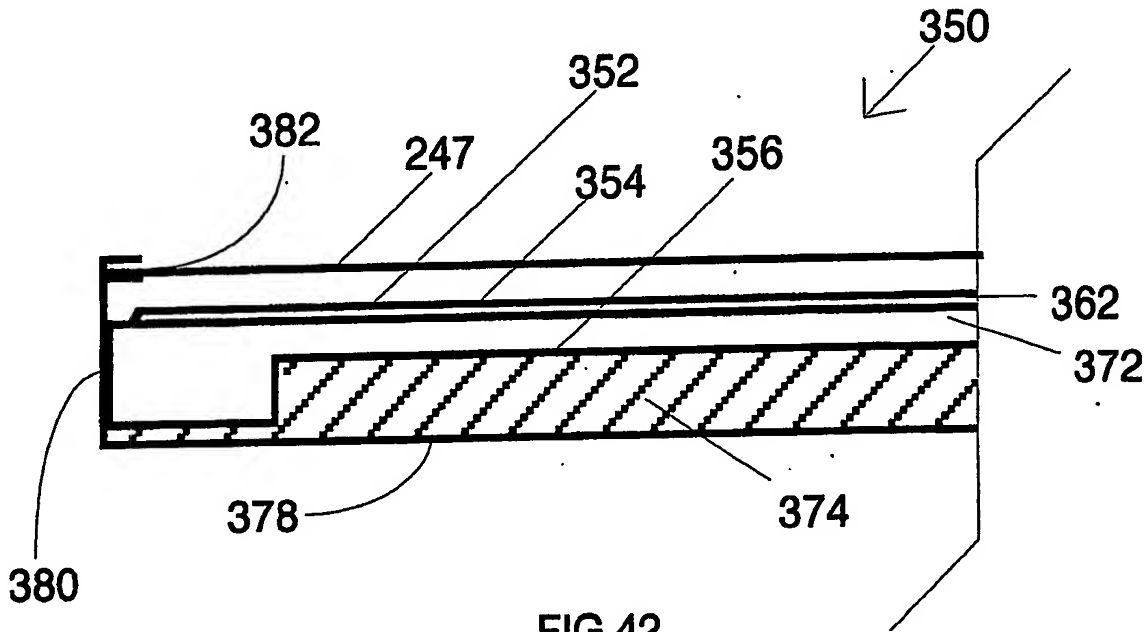

FIG 42

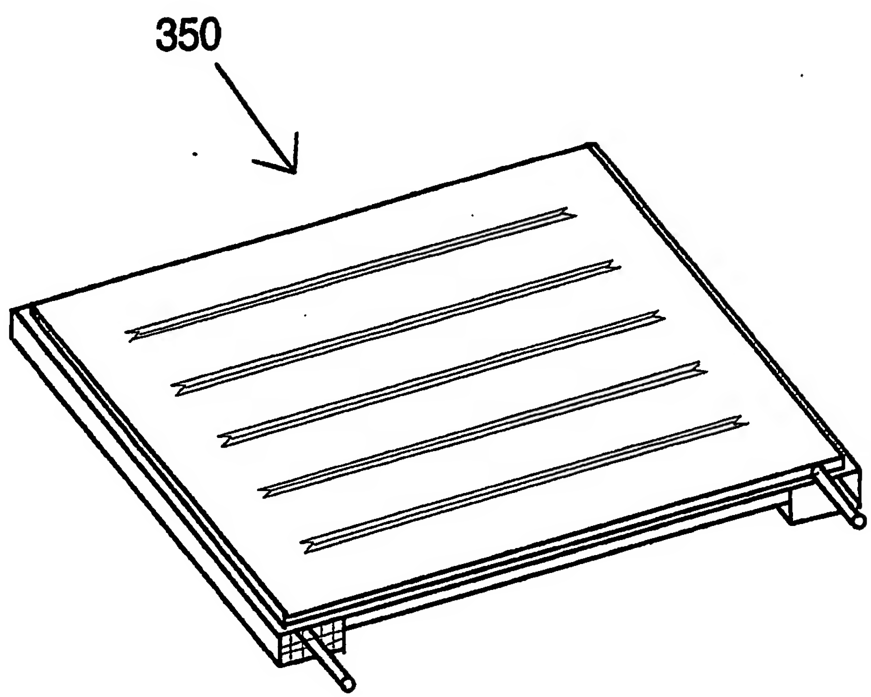

FIG 43

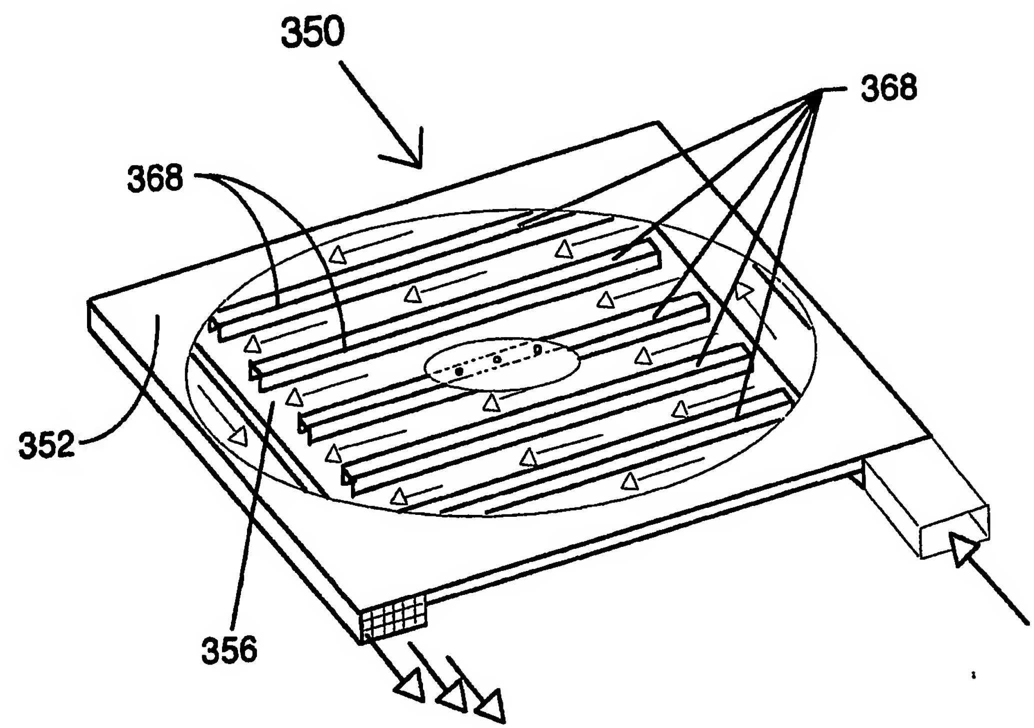

FIG 44

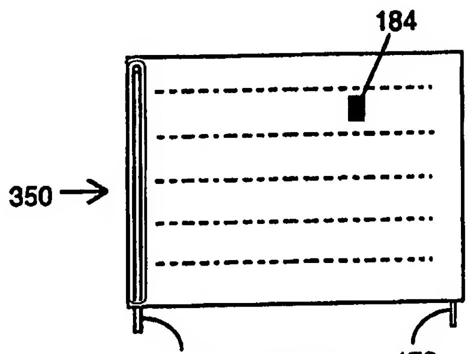

FIG 45 a

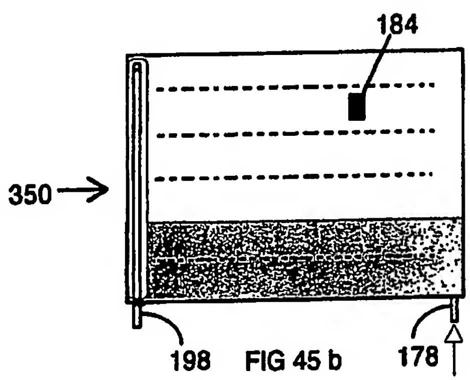

FIG 45 b

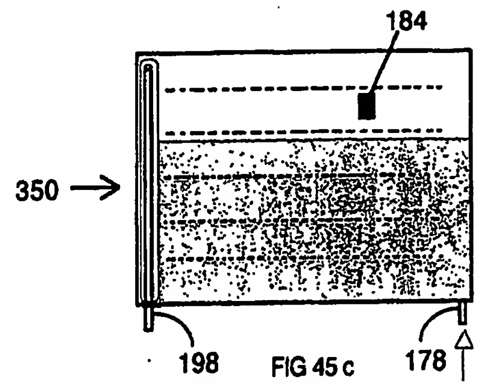

FIG 45 c

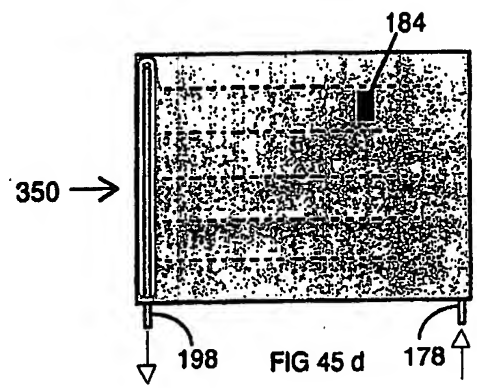

FIG 45 d

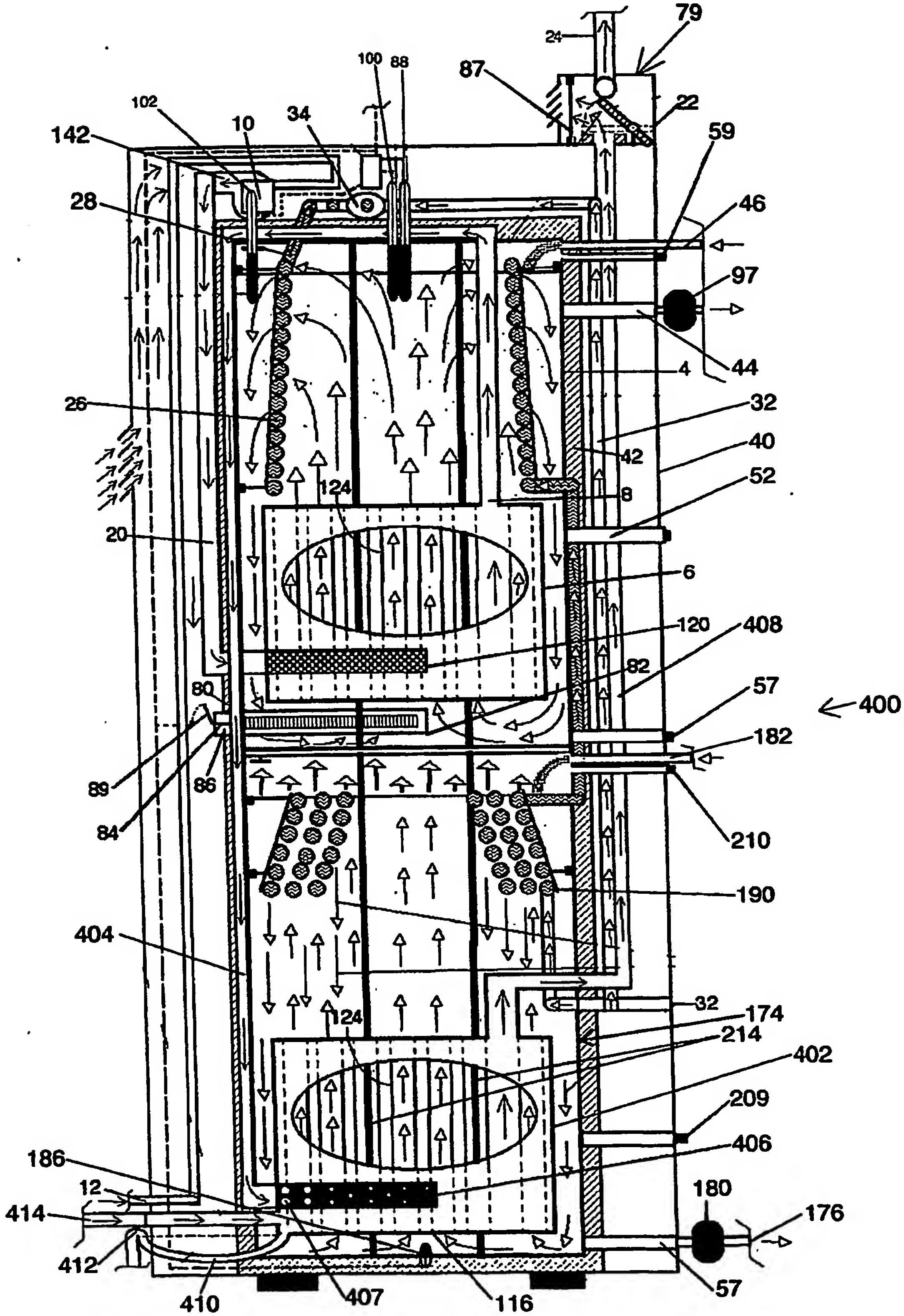

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FIG 46

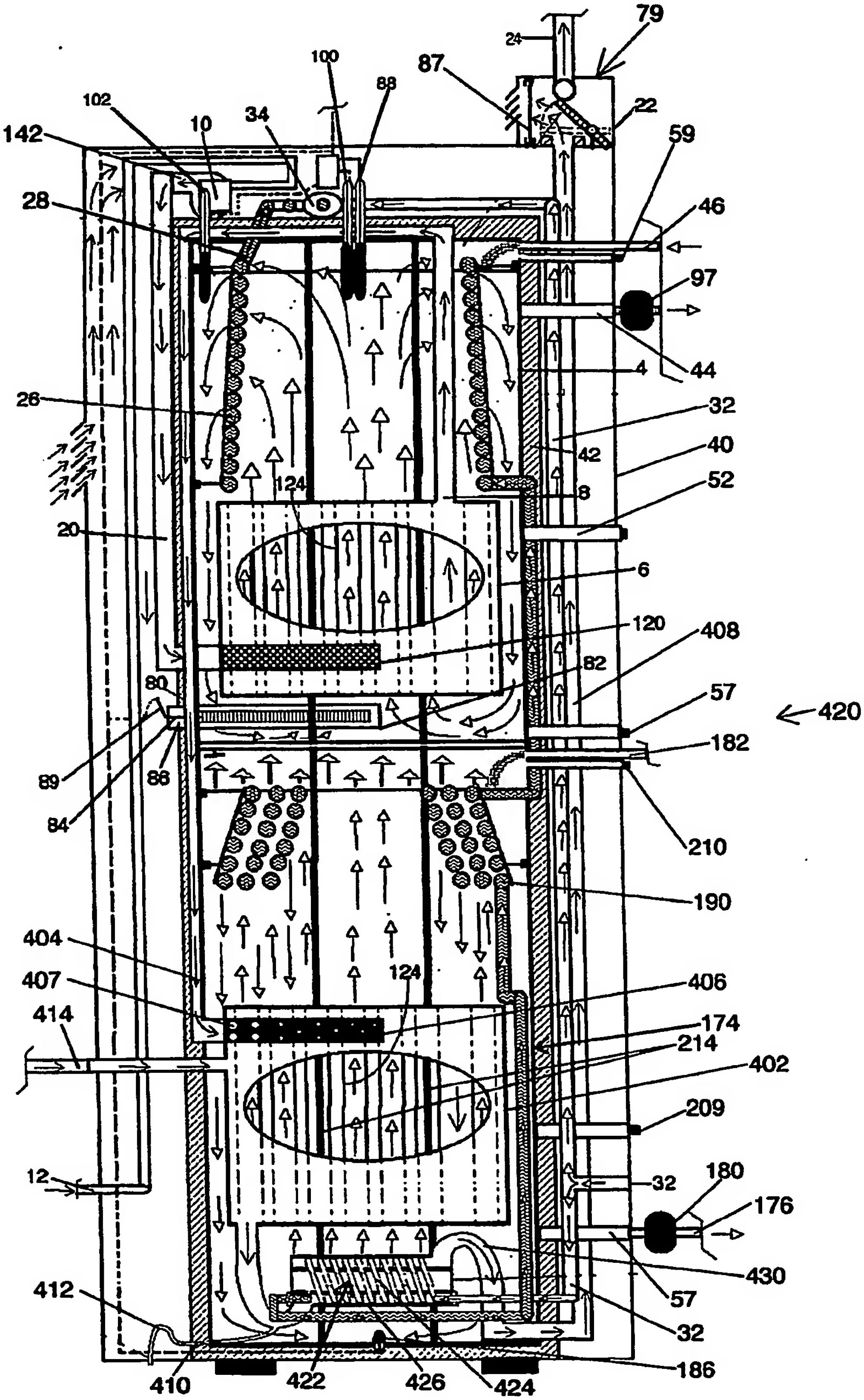

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FIG 47

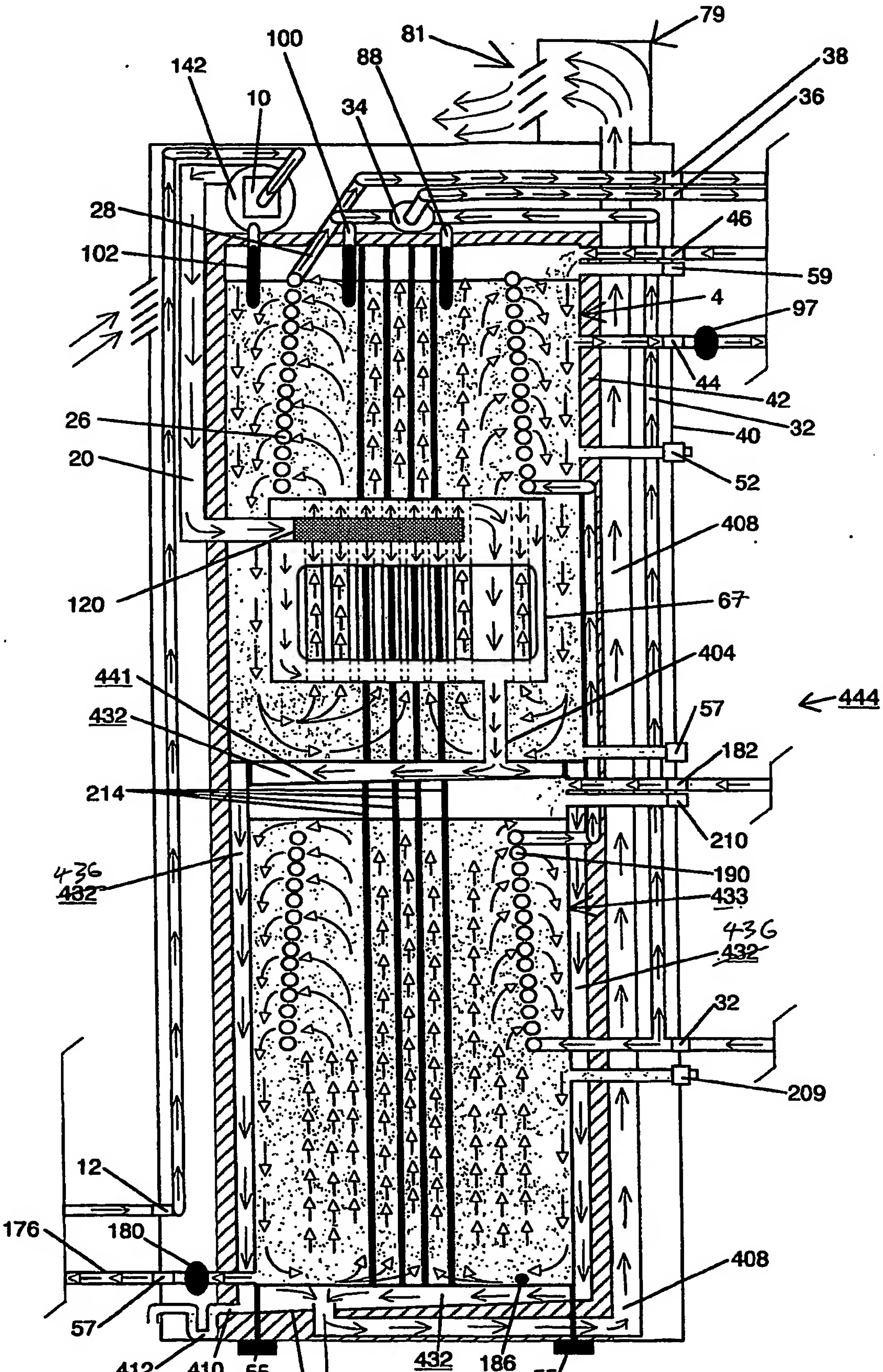
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FIG 48

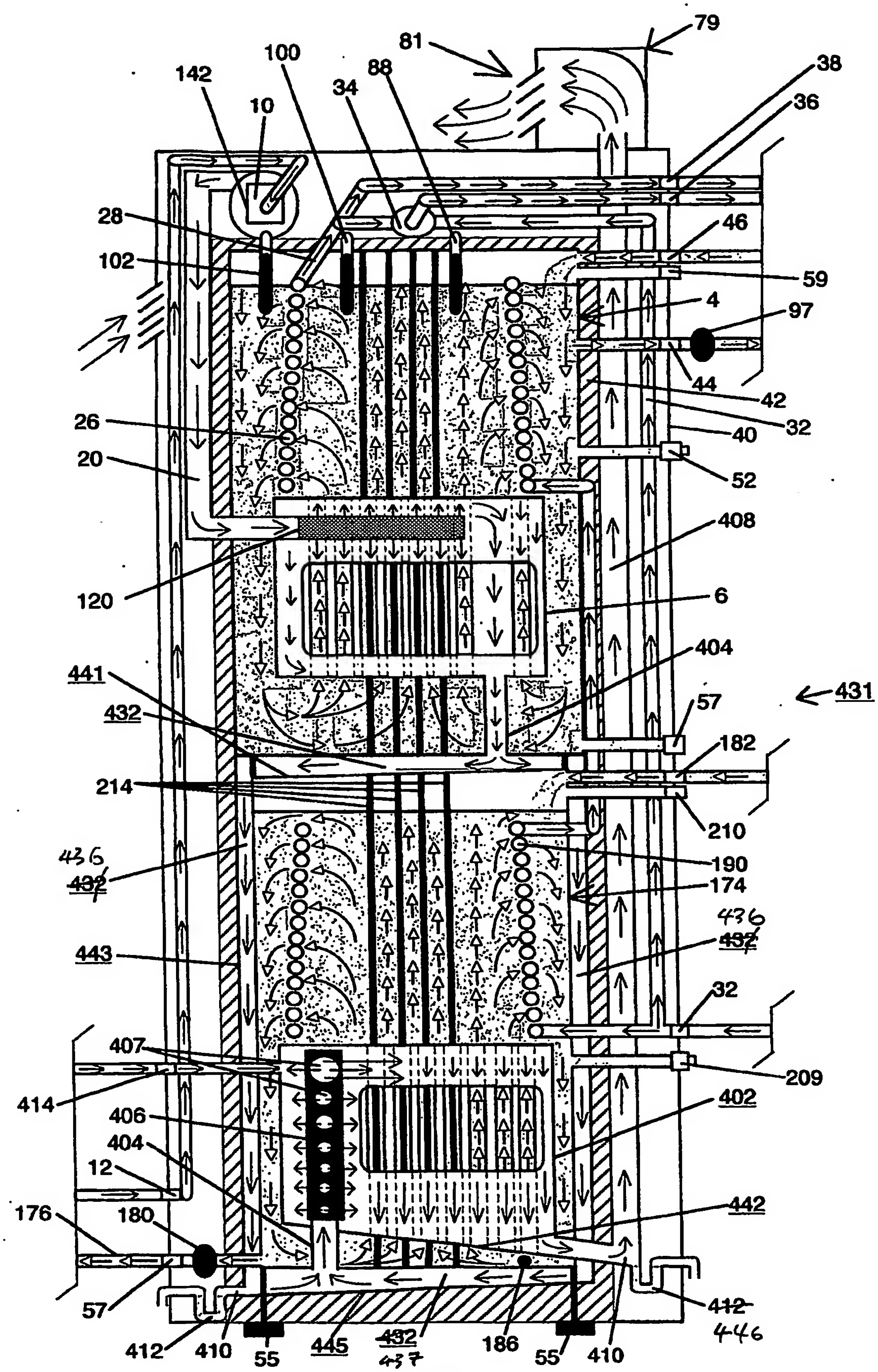
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FIG 49